Air Traffic Control

Radio Technical Commission for Aeronautics

May 12, 1948

RADIO TECHNICAL COMMISSION

for

AERONAUTICS

Washington, D. C.

AIR TRAFFIC CONTROL

PAPER 27-48/DO-12

Prepared by RTCA Special Committee 31

* * *

May 12, 1948

* * *

Supersedes:
1. RTCA Paper [illegible]-48/DO-9 dated 2-16-48
2. RTCA Paper 10-48/DO-10 dated 2-17-48

Price [illegible]

AIR TRAFFIC CONTROL

TABLE OF CONTENTS

Page
Foreword 1
Introduction 2

Summary of the RTCA Program for an All-Weather Air Traffic Control System 5

SECTION I

A. Fundamental Objectives of Air Traffic Control 11
B. Basic Air Traffic Control Principles 11

SECTION II

A. Operational Requirements of An Air Traffic Control System 13
B. Operational and Air Traffic Control Areas 14
C. Basic Equipment Elements of the Air Navigation and Traffic Control System. 15
D. Narrative Description of Air Traffic Control System Operation 18

SECTION III

A. Equipments of the Transition Period 21
B. Evolution of the Operational Use of the Equipment 26
C. Integration. 30
D. Administration 31
E. Time and Cost Factors 31
F. Radio Frequency Spectrum Requirements 34

APPENDIX I

A. Operating Principles and System Requirements 36
B. Operational Procedures Predicated Upon the Air Traffic Control Principles . . . . .
Developed. 40

APPENDIX II

A. Operating Procedures 41
B. General Operational Plan 42
C. Detailed Operational Plan 43
D. Chart I Explanation 44
E. Chart II Explanation 47

APPENDIX III

A. Traffic Control Equipment (Airborne - Equipment # 1) 53

Requirements for the Ultimate System. 53
Requirements for the Interim System - Transponder 54
Requirements for the Interim System - Private Line 54

B. Navigational Equipment (Airborne - Equipment 42) 55
C. Airborne Display (Pictorial and Symbolic - Equipments #l(b) and #2(b)) 58
D. Traffic Data Relay Equipment (Ground - Equipment #3). 59

Secondary Radar - Requirements for the Ultimate System 59
Secondary Radar - Requirements for the Interim System 60
Private Line - Requirements for the Ultimate System 60
Private Line - Requirements for the Interim System 61

E. Automatic Air Traffic Control Equipment (Ground - Equipment 44) 61

Airspace Separation Element (Equipment #4(a)) 61

Continued Page

Flow Control Element (Equipment 44(b)). 62
Display for Use by Detail Flow Control Unit (Pictorial _ Equipment #4(e)) : : : 63
Display for Use by Detail Flow Control Unit (Symbolic - Equipment #4(c)), . , 63
Flight Path Planning Element (Equipment #4(c)).. 64
Airport Time Utilization Element (Equipment #4(d)) 66
Display for General Planning Unit (Symbolic - Equiprnent #4(f))' : : : : 1 : 1 1 67

Airport Equipment (Ground - Equipment #5).. 68
Landing Navigation and Monitoring Equipment Equipment #6). . . , , . . 1 1 : : : 70

Landing Monitoring Equipment (Equipment #6 (a)) 70
Landing Navigation Equipment (Equipment #6 (b)) 71

4 Airport Surface Navigation and Monitoring Equipment (Equipment #7) 74

Airport Surface Movement Equipment (Equipment #7 (a)) 74
Airport Surface Navigation Equipment (Equipment #7(b)) 74

Airport Utilization Planning and Control Equipment (Equipment #8). 75

Intercommunication Equipment (Equipment #9). 76

Interphone Equipment 76
Automatic A.T.C. Point-to-Point Communication . . . . . , ... 77
Microwave and/or Coaxial Cable Point-to-Point Relay Circuits (Ground) . . . 77

and Primary Surveillance Radars. 78

Ultimate Requirements 78
Interim Requirements . . . . : 1 : : : : : : 79

. Traffic Control System Simulator 79

APPENDIX IV

from Final Acts of the International Telecommunication and Radio Conferences
ment Relating to the 1947 Meetings at Atlantic City. 81

APPENDIX V

. . . . 84

APPENDIX VI

- - Special Committee SC31 - Air Traffic Control 87

ATTACHMENT

Papers 9-48/DO-9 and 10-48/DO-10 90

FOREWORD

This report, prepared by RTCA Special Committee SC31, was accepted by the Executive Committee of the Radio Technical Commission for Aeronautics under date of February 17, 1948. It thereby becomes an official Paper of RTCA and is distributed as such.

The RTCA is a cooperative association of all United States Government - Industry aeronautical telecommunication agencies. It conducts studies of aeronautical telecommunication problems and related matters. Its objective is the resolution of such problems by mutual agreement of its member agencies. Its findings are in the nature of recommendations to all United States organizations concerned.

The RTCA is not an official agency of the United States Government. Its recommendations, therefore, may not be regarded as statements of official government policy unless so enunciated by the government agency, or agencies, having statutory jurisdiction in the matters to which the recommendations relate.

INTRODUCTION

Under date of Apri! 28, 1947, the Technical Division of the Air Coordinating Committee requested the Radio Technical Commission for Aeronautics to undertake a study of Air Traffic Control for the purpose of developing recommendations for the safe control of expanding air traffic.

In accordance with this request, the Executive Committee of RTCA established, on June 12, 1947, a Special Committee designated "SC31 - Air Traffic Control" with the following directive:

"The Executive Committee of RTCA recognizes the importance of resolving the problems involved in Air Traffic Control. It is especially important that the Committee be suitably impressed that any system of Air Traffic Control be applicable to all users of the airspace.

"It is intended that the work of the Committee be divided into two phases, as follows:

"A. Development of basic Air Traffic Control principles (Phase I)

"B. Development of recommendations regarding equipments and procedures required to implement the Air Traffic Control principles (Phase II)

"Traffic Control Principles, Phase I

"For the purposes of the work of SC31,Traffic Control is defined as those procedures required to accomplish the following:

"A. The efficient use of the navigable airspace and landing areas.

"B. The expeditious movement of all classes of aircraft under conditions when control is required.

"C. The avoidance of collision between aircraft.

"Some of the problems involved in the realization of the objectives set forth under A, B, and C above are as follows:

"A. The efficient use of navigable airspace and landing areas.

"1. A determination as to whether aircraft operations shall be based upon utilization of airways only or of the entire navigable airspace.

"2. Investigation of the advisability of establishing a maximum aircraft acceptance rate for landing and takeoff at each airport to govern the flow of traffic into any given airport.

"(a) It is probable that predication of aircraft movements upon the acceptance rate for any given airport will require that the time be proportioned between various classes of service employing the airport.

"3. A determination as to whether traffic control should be made applicable to all flight movements and. if so, whether separate procedures should be established for unrestricted and restricted visibility weather conditions.

"B. The expeditious movement of all classes of aircraft under conditions when control is required:

"1. Scheduling

"(a) By time table (general schedule)

"(b) To meet the existing traffic situation (immediate schedule)

"2. Flight Planning

"(a) By the pilot for approval by the ground, or

"(b) By the ground for complete guidance of the pilot, or

"(c) By the ground of arrival time only and by the pilot to make good the approved time of arrival.

"3. Procedures

"(a) To provide complete control by the ground on the basis of information furnished to the ground by the aircraft, or

"(b) To provide complete control by the pilot as long as an approved flight plan is made good with provisions to obtain approval oi a new flight plan from the ground when necessary, or

"(c) The establishment of a joint responsibility between the ground and the pilot'of an aircraft by giving information to both the pilot and the ground and with the ground having the overriding control authority.

"C. Avoidance of collision between aircraft

"1. By vesting full responsibility for the coordination of all aircraft movements with the ground, or

"2: By providing the pilot with informaiion which will permit him to avoid collision with other aircraft without assistance from the ground, or

"3. By a combination of 1 and 2 whereby the piiot is provided with necessary information to avoid collision but with a supplementary monitoring service rendered by the ground.

"Implementation of Air Traffic Control Principles, Phase II

"Initially, the Committee should draft a detailed description of the facilities required to fully implement the Air Traffic Control principles developed under Phase I of its activities.

"Secondly, the Committee should develop recommendations for any necessary revisions of the present system utilizing facilities and procedures now available with integrated plans for the addition of new facilities required to implement the final system. The dates of each phase of the implementation program from the present onward for equipment and its utilization should be stated.

"In both phases of its activities, the Committee should give serious consideration to the following factors:

"(a) Pilot utilization of the system with due regard to his other responsibilities in connection with the operation of the aircraft.

"(b) The use of the system in relation to National Defense.

"(c) Economic factors involved in the utilization of aircraft, costs of airborne and ground equipments, personnel, etc."

The membership of Special Committee 3 1 comprised representatives of all interested government and civil organizations. A listing of the names and affiliations of the Committee membership is included in this report under Appendix VI.

SUMMARY

OF THE
RTCA PROGRAM FOR AN ALL-WEATHER AIR
TRAFFIC CONTROL SYSTEM

In the interest of national defense and national welfare, an integrated system of air traffic control is a vital necessity. The RTCA program is intended to meet both military and civil requirements. It is not a compromise. It is a common solution that is best for each service. The same system with the same tools gives the military maximum safety when operated to whatever capacity is required by military necessity. It gives the civil maximum capacity when operated to a specified standard of safety.

The Need

All aircraft In a region must be accounted for; any unidentified aircraft must be promptly investigated. These measures will permit the first action to be taken after initial warning of a surprise attack. While a rudimentary system was set up for this purpose in the recent war with human watchers reporting all passing aircraft into a central control agency, in overcast weather the position determination was possible by area only and, in no case, could precise identity be determined. The breakdown of a simple location system without identity was high-lighted by the Pearl Harbor attack.

Ability to clear civil aircraft out of a combat region and to direct fighter planes into the region and control their actions is a second and equally important consideration. It is particularly important to be able to land combat planes rapidly in any weather, refuel them, and return them to the battle promptly.

In the event of a national emergency, both civil and military aviation will be called upon to move key men and equipment. Air terminals, where traffic is normally low, can be called upon suddenly to handle more aircraft than now fly into the New York area. In such a crisis, there is no time to build new airfields to meet the required expansion. Into this congested area would fly many military aircraft from storage. The only method of meeting such a sudden demand for increased traffic is an effective air traffic control and navigaional system already in being before the crisis.

The airline pilots and well trained private pilots constitute an immediately available reserve on whom the military can draw for their initial expansion. It is highly desirable that all classes of pilots be trained in the use of the system well in advance. The confusion and disruption caused by a well planned surprise attack would probably paralyze the slightest attempt at education in the use of an unfamiliar system.

Integration of the air traffic control and navigation system with the air defense and early warning system will solve these problems.

Such an integrated system as part of the national security program wil1 be partiaily self-supporting. There will be an improvement in airline finances when the airlines are able to operate without cancelling trips. The United States airlines lost $22,000,000 net in 1947. In 1946, the airlines suffered losses of actual and potential revenue from various sources, as follows:

	Millions of Dollars
Cancellations due to weather	6.2
Low load factor resulting from unreliability	12.2
Congestion at 13 stations at which studies were made	21.1
TOTAL	39.5

Presumably, losses at other congested stations where studies were not made also contributed. The losses to private operators, military, contract, and non-scheduled services cannot be estimated but are certainly appreciable. It is thus seen that an effective all-weather air traffic control and navigation system would have saved considerable money.

This country has an estimated six billion dollars invested in civil airports which are closed approximately 15 per cent of the time due to weather. hll-weather flying would be equivalent to increasing our airport values by $900,000,000 even before an additional acre of land is condemned or a yard of concrete Is laid.

There are other less tangible but nevertheless real ecor.omic gains that can accrue by solving the **air** traffic control and navigational problem. The ability to get key personnel and products from one section of the country to another rapidly is a vital factor in production efficiency. The presence of the right man at a meeting may solve a knotty problem; rapid movement of critical component items may well prevent stoppage of production lines. At the present time, the use of air transport introduces uncertainty because of the ever present threat of flight cancellations.

The Present Situation

Every citizen having any acquaintance with flying knows well the inability of the existing techniques of traffic control to handle the present volume of air traffic, particularly under adverse weather conditions. The Civil Aeronautics Administration is charged by statute with regulation of air traffic. The tools available to the CAA to discharge this responsibility are marginal even by prewar standards. Traffic controllers are struggling valiantly to handle an increasingly difficult situation. At present, the only position information available to controllers are navigational estimates of positions reported by aircraft pilots. These may bc in error by many miles, either from instrument error in the aircraft or from delay in receipt of reports. The use of additional controllers will be of considerable benefit but, as traffic increases, will reach a point of diminishing returns. The **volume** of communication necessary with the present techniques is a limiting factor; in fact, over-saturation of communication channels already exists in some areas.

The position estimates received from the pilots of aircraft are manually posted and estimates are made from these postings to effect separation of aircraft. With this inefficient setup, the CAA controllers have indeed done an amazing job. It is true that, for safety reasons, passengers expecting to arrive at Washington at 6:30 p.m. may well land at Philadelphia at 11:45 p.m. The current system is cumbersome, bu! the controllers have conscientiously tried to keep it safe.

The CAA has recognized its need for improved tools for the control of air traffic. It has been hampered in obtaining them by the confusion of riches resulting from accelerated development in radio devices during the war. The laboratories of the armed services, of industry, and of the CAA itself have been most active in the application of war-born techniques to the problems of aerial navigation and the control of air traffic. Time has **been needed to** consolidate the results of these activities into a single working system suitable for national defense and civil aviation. It is believed that such consolidation is here accomplished and that the single system defined will serve throughout the foreseeable future.

The Cure

The fundamental principles which govern the design of a traffic control and navigation system are:

1. Aircraft must be flown safely.

   A satisfactory air traffic control and navigation system must maintain adequate separation between aircraft In operation and must prevent aircraft from colliding with fixed obstacles.

2. Air traffic must flow expeditiously.

   The expeditiousness of flight is highly desirable and must be limited only by the capacity of the installed runways and considerations **of** safety. The objective set up was that aircraft must be handled in instrument weather at the same rate as in contact weather.

3.- Airborne equipment must be universal, simple, and light.

   This fundamental arises from the fact that this equipment is required to serve three general classes of aircraft; namely, military, commercial air transport, and private and that the same class **of** service must be provided for all types of aircraft.

4. The system must impose a minimum burden on **the** pilot and on ground personnel.

   The fourth requirement arises from the fact that the pilot of a large aircraft already has so many instruments in front of him that a casual examination of the cockpit of a transport plane would convi**nce anyone that** exceptional skill and alertness are required to fly it. Ground coordination under present conditions is also highly involved.

5. The system must impose minimum cost on the taxpayer, **the** airlines, and the private pilot.

This last principle requires no justification.

Consideration of the five fundamental principles listed above with the realities of flight and of elcc- tronic equipment leads to the derivation of a set of secondary requirements which follow.

1. The system must be capable of being set up on a single site and provide navigation and traffic control out to a line-of-sight distance.'

   The requirement for single-site operation is largely a military one. It arises from the military need to control aircraft from an island, from a carrier, or from a small strip of beach - all without cooperation of any distant station. This requirement immediately eliminates consideration of all hyperbolic systems of navigation since they--require multiple sites. It focuses attcntion on systems using polar coordinates. It also eliminates consideration of all landing systems which require equipment placed a considerable distance from the airport, definitely concentrating attention on systems which operate on radio courses generated within the confines of the airport, While the requirement excludes from consideration many ingenious systems, it serves to concentrate attention on the few systems which will meet it and thus permits comprehensive study of them.

2. The system must provide identification of all airplanes.

   The second requirement arises both from the military necessity to spot enemy planes and the peacetime requirement that traffic clearances are, in fact, received by the proper plane.

3. The system must derive information to be used in traffic control from the ground equipment and information to be used in the airplane from the airborne equipment.

   The third requirement arises from the fact that if air-derived position information is used to maintain aircraft separation, it is possible for errors from two airborne equipments and from two ground equipments all to be additive. On the other hand, if the positional information for separation purposes is derived from a single ground equipment such as a radar, any error in the orientation of the radar is identical for all aircraft so that the relative separation information concerning the aircraft is substantially without error.

   In the same way, navigation information should ideally be derived in the aircraft wholly independent of any ground eqaipment. This is simply an expression of the principle of minimum reliance on others. Unfortunately, flat characterless terrain makes this impossible and requires some cooperation from ground equiptment. Omni-range and DME beacons are an example. However, attempting to navigate aircraft from information derived in the ground equipment requires positive identification of each aircraft in order that the pilot may be certain that the indication of his instruments actually regisrers his own position. Furthermore, sending navigation iniormntion from the ground to the aircraft means either group information with each pilot sorting out what pertains to him, excessive use of the radio spectrum, or delay due to time-sharing rhe same frequency.

   All navigation information should at times be checked against a ground fix. In low density areas, this may well be occasional, whereas in high density areas it should be almost continuous. Another consequence of this requirement is that all traffic information and clearance sent to a particular plane should. in fact, be acknowledged in detail. Both of these procedures help assure closed-circuit operation.

4. The system must operate on the closed-circuit principle.

   The "closed-circuit principle" asserts that the system must continuously report that it is operating correctly. This is a wholly different matter from giving an alarm when it is inoperative. It is a principle which has been recognized for years in signaling practice. The presence of air-derived data for navigation and ground-derived data for traffic control makes this fundamental requirement realizable for aerial operation.

5. All elements of the system must be interlocked (i.e., provision for protection of wrong action) so as to preclude the possibility of human error.

   Just as the closed-circuit principle is required to provide for error or failure oi equipment, so the interlock requirement provides against human errors without restricting **the** capacity of the system to handle heavy volumes of traffic.

6. A flow control system is required to sequence planes in crowded areas and complicated traffic patterns.

7. The system cannot be built by the addition of all desired techniques but must be designed with the minimum number of equipments necessary and with an eye toward an orderly evolution and integration.

The foregoing requirements lead directly to systems of navigation which locate an aircraft by its stance and direction with relation to a chosen point - the much discussed polar-coordinate or R-Theta stems. A program for installation of VHF omni-ranges and distance measuring equipment represents the most advanced embodiment of this principle. Ultimately, and as part of the RTCA system, the VHF :mni-ranges will have to be superseded by improved equipment. This is dictated by requirements of accuracy not met by the present equipment and by the necessity of consolidating all short distance navigational services for air traffic control in a single radio frequency band. Such consolidation will effect implification in the equipment to be carried by aircraft.

Indeed, the RTCA system consolidates into a single equipment all the services required for navigaion and instrument landing, radiocommunication for traffic control, and a map-like picture which furtishes a double check to the pilot of his navigation and gives him a means to monitor the traffic situation and the movements of other aircraft in his vicinity. It is recognized that the smaller aircraft may not **be** able to carry the pictorial display.

The requirement that traffic control information be derived from ground equipment is readily met by a radar-type technique. It would here be desirable that the ground equipment provide not only R and Theta of the individual aircraft but also altitude and identity. Since present day radars do not provide the last two, it is necessary to install a transponder in the aircraft; this can be altitude coded and can also be operated to provide identity on request. With this equipment, the basic requirement that air traf-ffic control information be derived from ground equipment is fulfilled. The ground equipment also operates from a single site.

Closed-circuit reliability is provided by furnishing both the pilot and the ground controller duplicate -formation independently. In order to transmit clearance to the airplane without cluttering up the aura! communication lines, the system establishes **a** private line between ground and each individual airplane. Since not enough frequencies are available to give a separate one to each aircraft, a small group of frequencies are postulated; time sharing gives a specific channel to each individual plane. Arrangement is made to send a small number of clearances to the aircraft such as “proceed”, “hold”, “go left”, “go right." "go up”, “go down”, and for the aircraft to transmit back to the ground a complete detailed acknowledgment.. This channel can also be used for pilot requests and reports with interlock acknowledgment coming from the ground and for periodic reports of the navigational situation as seen on the pilot’s instrument board. The comparison of the signals from the private line indicator in the aircraft with the tuation on the pictorial display or the navigation instruments gives the pilot closed-circuit protection. comparison between the positioon as determined by the ground radar and as reported over the private nes gives closed-circuit monitoring to the ground.

An additional requirement to be met is the interlock requirement. This requires two functions to be fulfilled one that the ground always monitor the plane’s actions to make sure that the pilot has executed by clearances sent to him over the private line, the other is an interlocking of the gruund equipment to prevent the issuance of hazardous clearances.

To keep the safety requircmen?s of the system, a fail-safe airspace separation system similar in ceration to a block control element is **specified.** This element overrides all other sources of traffic in**formation and** clearance to the aircraft so that it is impossible either for any automatic or manual system to send unsafe clearances to any aircraft.

Even with aircraft flown safely and with all the above requirements fulfilled, much is left to be de**red** Separate studies made by independent agencies show that it is not expeditious to allow aircraft to -rive **at** a crowded terminal area without previous sequencing and speed control. In the New York area under present conditions, deviations of as little as three minutes from an estimated arrival can cause serious delay. To attempt to land even 21 aircraft per hour per runway will result in an average delay of ' minutes. Delays to some aircraft will be almost an hour.

Expeditious flight can be assured by advance planning to insure runway availability at or near tbe projected arrival time by checking proposed flight paths against all those previously approved and by monitoring and re-sequencing of aircraft to achieve masimum utilization of runways. If this is prcperly done, almost all planes take up any necessary delays on the airway and make straight-in approaches and immediate landings. Control of arrival time by varying departure time, path length, and speed within reasonable limits imposes minimum strain on passengers or pilots in comparison to present day holding in a confined airspace.

The flow control in a low traffic area can be established by occasional position reports from the aircraft to the controller, manual posting boards, and manual sequencing. In the most crowded areas, continual radar position determination, automatic monitoring, and re-sequencing of aircraft, where necessary, will be required. The major item of this latter system is a computer which receives reports from the radar system, desired flight plans from a flight path planning equipment, and information concerning weather, icing conditions, and the like which might temporarily close off certain air lanes. Based on this information, the flow control system monitors the flight of all aircraft in its area to determine if the plane Is, in fact, making good its desired flight path to ensure that any changes introduced into the flight path, due to pilot error or change of weather, have not introduced hazardous conditions.

The final requirement expresses the acute need of careful system engineering rather than unplanned accumulation of gadgetry. With the wealth of ingenious systems which have been recently suggested, it would have been easy for agreement to have been reached by addition. This was not done. Only those elements were selected which are necessary and sufficient for the solution of the problem. Invention in assembly was guarded against. The underlying techniques required in each of the components of the system are well known; considerable engineering development will be required to produce the practical applications of these techniques in working equipment. This portion of the program merits the highest priority.

The Cost

The cost of the total system is estimated at $1,113 million. Of this total, $897 million is required for national defense which includes ground equipment and military airborne equipment. Requisite civil airborne installations are estimated at $216 million. Included in the total cost are $75.4 million for the development of equipments needed in the target system but which are not now at hand..

The proposed system represents not over 5 per cent of the present investment in aviation in the United States. The increase in reliability obtainable under the proposed system will go far toward making aviation a self-sustaining industry.

The cost figures cited are based on the assumption of an orderly evolution from the present system through a period of integration to the target system. Any significant deviation from this plan will almost certainly result in these estimates being seriously exceeded.

The Execution of the Program

To assure that continuity is maintained in implementing the RTCA program for an all-weather air traffic control system, it is recommended that a permanent Air Traffic Control and Navigation Steering Committee be established, to include representation from all users of the airspace.

The program requires some fifteen years for complete development, installation, and training of operators. Meanwhile, it is essential that something be done to relieve the present congested condition of the airways in the interest of national defense. Furthermore, the present rate of loss of aircraft and the present irregularity of flight dampen the desire of the American people to fly.

To overcome this condition, an immediate interim program is proposed to be completely installed and operating within a five-year periodd. This comprises a low cost, lightweight VHF receiver to permit use of static-free voice channels and omni-directional range naviagation on small aircraft. Additional ILS and GCA installations are required. The completion of the testing and production of distance measuring equipments and course computers is required so that aircraft can navigate with assurance. The completion of a radar cover of the more crowded traffic areas and the installation of airborne transponders in all aircraft capable of planned instrument flight are important portions of the interim program. The RTCA program utilizes the existing air navigation and traffic control facilities in the interim period.

A VHF automatic direction finder equipment at airports is recommended and also a simple mechanical interlock board to assist harassed traffic controllers and tower operators. Of these, the only equipment which cannot be integrated into the final target system is the VHF automatic direction finder and even this equipment may well prove useful in the lower density areas on the edge of the radar network. The cost of this interim program is estimated to be $375.2 mullions, of which only two per cent is for completion of the development of these equipments. most of which are now at least in the model stage.

the estimates of cost and time required to complete the programs, it was found that the required could be substantially decreased if development contracts could be permitted [illegible] of five years instead of the present two-year limitation. Many contracts could be best [illegible]. Commercial interest could be sustained in complicated development obiigations [illegible] production is assured.

[illegible] of the complete requirements for air traffic control and navigation, using both avail- [illegible] facilities, shows:

1. Present facilities provide a factor of merit of 42 per cent.

2. The facilities of the interim program will provide a factor of merit of 6'7 per cent.

3. Full implementation of the RTCX system will provide a factor of merit of 95 per cent.

Time for the full lmplementation of the RTCA system could be reduced materially by revision of [illegible] contractual policies.

SECTION I

A. FUNDAMENTAL OI3JECTIVES OF AIR TRAFFIC CONTROL

The flight operational requirements to be satisfied by Air Traffic Control are detailed and complex. **Among** the factors involved are the horizontal, vertical, and Interal movement of aircraft; the use of a common airspace by aircraft of widnly varying speeds and performance characteristics; the **types** of service, both civil and military, for which aircraft are employed; the restrictions imposed on aircraft operations by weather conditions; the number of flight paths available to aircraft for en-route operations and the convergence of these flight paths in the vicinity of terminals. These **and** other factors must be considered in developing a satisfactory System* for Air Traffic Control.

The fundamental objectives which must be satisfied are:

1. The Air Traffic Control System shall insure safe separation between aircraft in operation and maintain the efficient and expeditious movement of all aircraft.

2. The Air Traffic Control System shall be capable of equitable and efficient use for military and civil aeronautical operations in time of peace and of efficient use for military operations in time of war or national emergency.

3. The Air Traffic Control System shall be capable of application to all aircraft in all usable airspace under all weather conditions.

B. BASIC AIR TRAFFIC CONTROL PRINCIPLES

The foregoing fundamental objectives require that the following basic principles be satisfied.

1.	SAFETY	The safe operation of all aircraft requires that **adequate** separation of aircraft be maintained at all times and under all conditions.
2.	EXPEDITIOUSNESS	The expeditious movement of aircraft requires airspace utilization under all conditions equal to chat under VFR conditions.
3.	RELIABILITY	The System shall, as far as possible, be independent of weather conditions and equipment breakdown.
4.	ALL AIRCRAFT USE	The System shall be usable by 311 types of aircraft in a manner compatible with their performance characteris-tic's and operational applications.
5.	ALL WEATHER	The System shall function effectively during all weather **conditions.**
6.	ALL AIRSPACE	**The** System shall be capable **of** expansion to include all usable **airspace.**
7.	MINIMUM CONTROL	The System shall provide control that imposes a minimum of restriction on the movement of the aircraft.
8.	INTEGRATION	The elements of the System shall be integrated.
9.	HUMAN FACTORS	The System shall impose a minimum burden on such human factors as competency, training, and alertness of **air** and ground personnel.
10.	EVOLUTION	**The** System shall permit orderly transition from the utilization of established Air Traffic Control aids to those ultimately required.
11.	FLEXIBILITY	The System shall incorporate characteristc which make practicable the handling of a wide variety of operation31 situations.

*The word "System" includes Air Traffic Control facilities, procedures, and personnel.

12.	SECURITY	The System shall be designed with due consideration for system security in the interest of National Defense.
13.	LIMITATION OF TRAFFIC FLOW	The System, in itself, shall not limit traffic flow below the acceptance rate of the airports.
14.	LANGUAGE DIFFICULTIES	The System shall operate independently of the language capabilities of ground and airborne personnel.
15.	IDENTIFICATION	The System shall provide a means of identifying aircraft as required for purposes of traffic control and in the interest of National Security.
16.	DIVISION OF RESPONSIBILITY	The Traffic Control Agency shall be responsible for Air Traffic Control planning, the collection of pertinent information, and the dissemination of traffic clearances and information. The pilot shall be responsible for compliance with the control agency's clearances, subject to a primary responsibility for the safe conduct of the flight. The appropriate regulatory authority shall promulgate rules and regulations required for the proper functioning of the Air Traffic Control System.
17.	DIVISION OF EQUIPMENT	The System shall place the primary burden of weight, volume, and physical complexity of equipment on the ground. The aircraft equipments shall result in the minimum detriment to aircraft performance.
18.	FREQUENCY	The frequency allocations for the System shall be consistent with National and International Tables of Frequency Allocations.
19.	COST	The cost of the System shall be compatible with the results obtained.

SECTION II

A. OPERATIONAL REQUIREMENTS OF AN AIR TRAFFIC CONTROL SYSTEM

One of the primary advantages of aircraft as a means of transportation is the ability to travel a direct route from the point of departure to the intended destination without regard to any of the terrain characteristics which affect the routes followed by surface vehicles. The most desirable system of Air Traffic Control is one which permits advantage to be taken of this aircraft characteristic. In general, this objective may be realized. However, in areas of high traffic density, the complexity of Air Traffic Control requires that definite travel routes (airways) be established.

1. There are two primary operational functions of the Air Traffic Control System. These two functions are of equal importance. They are:

   a. Maintenance of safe separation between aircraft.

   b. The expeditious handling of aircraft in operation, or desiring to operate, in the System.

2. To maintain safe separation of aircraft without impeding the flow of traffic:

   a. The System shall provide safe separation by automatic means.

   b. The System shall be so designed that mechanical or electrical failure cannot give a dangerously false indication.

   c. The System shall have the ability to reserve a prescribed airspace for the next intended move, whether this move is straight ahead, reverse course, up, down, right, or leit.

   d. The System requires that discrete contiguous units of airspace be established. These units shall be of such size as to permit necessary aircraft maneuvers without introducing a collision hazard.

3. To handle traffic expeditiously:

   a. The System shall arrange the flow of traffic automatically to realize maximum utilization of the runways with minimum average delays to aircraft.

   b. The System shall indicate when and where aircraft can be inserted in the traffic flou so that they can be sequenced automatically by lane and time.

4. To maintain both expeditious flow and safe separation simultaneously:

   a. The System shall permit insertion of new traffic into the traffic flow at any point enroute and shall permit the rearrangement of traffic flow to handle emergencies, special priorities, and other irregularities.

   b. The System shall provide the means for controlling aircraft experiencing equipment failure.

   c. The System shall provide means for controlling aircraft flying on courses other than discrete lanes.

   d. The System shall automatically transmit to the aircraft, and display therein, traffic control clearances such as go up, go down, go right, go left, hold, proceed.

   e. The System shall utilize time as the factor to establish and maintain a plan of operation for moving aircraft in the system.

   f. The System shall segregate aircraft into different speed categories whenever necessary to increase the capacity of the system. The system must not preclude, however, use of the same traffic lane by aircraft of different speeds.

   g. The System shall readjust automatically the flow or sequence of aircraft uhen conditions such as hazardous weather require a Lengthening of the proposed flight track.

h. The System shall be capable of handling unexpected diversion of aircraft, interruptions, changes in routing made necessary by changing, wind direction, and other operational variables.

1. The System shall achieve the final precise flow of traffic to the runways with the minimum of restriction at each stage of the flight. It shall permit a maximum of time tolerance in each stage of the operation consistent with the required operational capacity.

j. The System shall provide for collection, transmission, storage, and display of information pertinent to the operation of aircraft in the system. Information on every aircraft in the system need not be displayed all at one time. Provision shall be made for selecting the area desired to be displayed. Warning of conflicts and emergencies shall be provided. Means shall be available to change traffic patterns and to provide for issuance of information to aircraft as may be required.

B. OPERATIONAL AND AIR TRAFFIC CONTROL AREAS

Air traffic control operational requirements are determined by flight procedures which differ in the various phases of flight operations. To permit a proper classification of each phase of the flight procedures, the following areas are established:

1. Operational

a. The Enroute Areas, which consist of the following:

(1) The Airway Areas which comprise that part of the navigable airspace over published routes with defined boundaries.

(2) The Off-Airway Areas which comprise that part of the navigable airspace outside of al1 other operational areas.

b. The Terminal Area, which has a radius of approximately thirty (30) miles and an estimated altitude of 7000 feet and which consists of the following:

(1) The Final Approach and Live Runway Area which comprises the surface of each live landing runway and the airspace used for direct approach thereto. This area extends from two (2) to ten (10) miles from the end of the live runway is approximately two (2) miles wide, and has an upper limit of 1000 feet above the glide slope and a lower limit extending to the ground A Terminal Area may contain one or more airports. An airport may have two or more Final Approach Areas in use simultaneously.

The term “airport” applies to land, water, and shipborne live runways and taxi areas.

(2) The Initial Approach Area which comprises the navigable airspace between the Enroute Area and the Final Approach Area excluding Holding and Departure Areas.

(3) The Holding Area which comprises those parts of the terminal airspace used for holding aircraft.

(4) The Departure Area which comprises tha! part of the terminal airspace used by departing aircraft.

c. The Airport Taxi Area, which consists of that area of the airport used for taxiing, excluding the live runway or runways.

2. Control

For purposes of traffic control the navigable airspace is divided into areas of control responsibility as follows:

a. General *Control Areas*

These areas are conveniently Iarge sections of *airspace* that form a mosaic covering the entire country. Each General Control Area includes ail of the Enroute and Terminal Areas within its boundaries. except those portions of the Terminal Areas covered by the Airport Control *Areas.*

b. Airport Control Areas

These areas comprise 'the surface of the airport and that airspace abou! the airport in which control of arriving and departing aircraft is exercised.

Traffic control functions within these two areas are handled by the following:

a. In The General control Area

(1) General Planning Unit - The personnel, with their equipment, that establish from the forecast the general flow of traffic for the-General Control Area.

(2) Detail Flow Control Unit - The personnel, with their equipment, that plan the utilization of the air lanes and organize traffic flow to carry out in detail the genera1 plan.

h In The Airport Control Area

(I) Airport Control Unit - The personnel, with their equipment, that plan the utilization of the air lanes and airport surface and organize detail traffic flow in the Airport Control Area.

BASIC EQUIPMENT ELEMENTS OF THE AIR NAVIGATION AND TRAFFIC CONTROL SYSTEM

Aircraft Equipment

The aircraft equipment of the system comprises two equipments: the Traffic Control Equipment and the Navigation Equipment.

a. The Traffic Control Equipment (Equipment #1 of Figure No. 1) is a transmitter-receiver having a small number of channels. This equipment with associated ground equipment:

(1) Automatically responds to secondary radar interrogation, thereby providing the ground with the aircraft's position in distance and bearing.

(2) Provides automatic transmission of altitude continuously and identity periodically when interrogated. Provision has been made, however, so that this information may be transmitted manually.

(3) Provides the ground periodically with information as to the aircraft's position as determined by the airborne navigation equipment for ground check.

(4) Provides private line* communication over which

(a) The pilot may transmit requests for information to the ground.

(b) The ground may issue traffic clearances to the aircraft.

(c) Either source will be provided automatic acknowledgment of message reception,

(d) The above information will be displayed by indicator signals.

b. The Navigation Equipment (Equipment #2 of Figure No. 1) is a transmitter-receiver having multiple channels. This equipment with associated ground equipment:

(1) Provides distance and bearing information for navigation. These data, when used in conjunction with a computer, will allow the pilot to fly any desired course.

(2) Provides precise slope, localizer, and distance information for instrument approaches.

(3) Provides information for airport surface navigation to enable the pilot to taxi his aircraft.

(4) Provides air-ground aural communication of a reliable and static-free type.

---

* Private line as used herein means a communication channel with its terminal equipment which connects each aircraft with the Traffic Control Agency.

(5) Provides a situation display in pictorial form which enables the pilot to monitor traffic conditions in his vicinity or receive other pertinent data such as holding areas, airlanc locations, and weather maps from the ground.

(6) Provides suitable output to allow. the aircraft to be automatically flown, either enroute or during final approach and landing..

2. Ground Equipment

a. Traffic Data Relay Equipment (Equipment #3 of Figure No. 1). This equipment comprises two elements: secondary radar and the private line transmitter-receiver.

(1) The secondary radar interrogates the aircraft Traffic Control Equipment and receives altitude, bearing, and distance information continuously and identification periodically. It, therefore, provides the ground with information as to the track being made good by the aircraft.

(2) The private line transmitter-receiver comprises the ground portion of the private line air-ground communications link. This equipment transmits traffic control clearances and information, safety separation signals, and acknowledgment of and answers to pilots' requests. From the aircraft, this equipment receives pilots' requests and confirmation of traffic control clearances. It also receives, at regular intervals, the air-derived navigation data and repeats it to the Automatic Air Traffic Control Equipment.

b. Automatic Air Traffic Control Equipment (Equipment #4 of Figure No. 1). This equipment comprises six elements: airspace separation, flow control, flight path planning, airport time utilization, detailed flow control, and general planning display equipments.

(1) Airspace Separation Equipment.

This equipment analyzes fixed airspace occupancy data autoomatically It prepares for transmission to the aircraft the necessary separation signals. These signals are transmitted over the private line.

(2) Flow Control Equipment

This equipment receives position and identity reports and compares these data with previously created flight paths to establish the sequence of movement of aircraft for expeditious traffic flow. It sends the clearances required for sequencing and flow control through the Airspace Separation Equipment to insure that unsafe clearances are not issued.

It compares the reports of the air-derived navigation information with the ground-derived position data and reports any significant deviations to the aircraft and to control personnel.

(3) Flight Path Planning Equipment

This equipment, when supplied with the quantities of aircraft planning to operate over specific routes to particular destinations, sets up flight paths to handle the traffic in the most efficient pattern.

(4) Airport Time Utilization Equipment

This equipment is designed to assure maximum utilization of runways. It receives requests for specific rights to land and landing times desired. It handles these requests, granting the landing times desired or offering alternate times.

(5) Detail Flow Control Display

This display is for use by the Detail Flow Control Unit. It provides both symbolic and pictorial displays of such portions of the General Control Area as may be desired at any particular time. The symbolic display includes current and proposed position data on individual aircraft. The pictorial display shows plan position, altitudc, approximate bearing of ground track, and identity of aircraft in the area.

(6) General Planning Display

This display presents symbolic information on aircraft which will arrive at or depart from airports within the General Control Area. It includes the general planning situation and information for approving requests for acceptance times.

(7) Voice communication with other control areas and aircraft is provided.

c. Nav-Aid Equipment (Equipment #5 of Figure No. 1). This equipment performs the following functions:

(1) Provides the aircraft with its bearing from the facility.

(2) Provides the aircraft with its distance from the facility.

(3) Provides static-free, aural communication.

(4) Provides transmission of the Situation Display received from the Traffic Data Relay Equipment, after being modified in the picture modifier.

d. Landing Navigation and Monitoring Equipment (Equipment #6 of Figure No. 1).

(1) The Landing Navigation Equipment performs the following functions on both landing and takeoff.

(a) Provides the aircraft with its lateral deviation from the center line and the extension of the center line of the live runway.

(b) Provides the aircraft with its vertical deviation from the glide slope being used.

(c) Provides the aircraft with its distance from the desired touchdown point.

(d) Provides static-free, aural communication.

(e) Provides transmission of Situation Display received from the Traffic Data Relay Equipment and Landing Monitor, after being modified in the picture modifier.

(2) The Landing Monitoring Equipment performs the following functions:

(a) Provides indication of the progress of aircraft in the Final Approach and Landing Area.

(b) Provides indication of the progress of aircraft in the Departure Area.

(c) Provides indications by which aural (GCA) controlled landing may be made.

(d) Provides indications which may be relayed to the Situation Display in the aircraft.

e. Airport Surface Navigation and Monitoring Equipment (Equipment #7 of Figure No. 1).

(1) The Airport Surface Navigation Equipment performs the following functions:

(a) Provides the? aircraft with the Situation Display necessary to enable the pilot to taxi on the airport surface.

(b) Provides static-free, aural communication.

(2) The Airport Surface Movement Equipment (Monitor) performs the following functions:

(a) Provides indications which can be used to monitor the airport traffic movements.

(b) Provides indications which may be relayed to the aircraft Situation Display.

f. Airport Utilization, Planning, and Control Equipment (Equipment #8 of Figure No. 1). This equipment comprises six elements: symbolic display (airport control area), symbolic display (airport surface), pictorial display {airport surface), pictorial display (landing), pictorial display (airport control area), and runway control equipment.

(1) Symbolic Display (Airport Control Area).

This display presents current and proposed positions of aircraft, including such detailed information as is required for aircraft operating in the Airport Control Area,

(2) Symbolic Display (Airport Surface).

This display presents, in symbolic form, the runways and taxiways in use at any particular time together with necessary controls.

(3) Pictorial Display (Airport Surface).

This display presents the positions of aircraft, vehicles, and obstructions on the airport surface.

(4) Pictorial Display (Landing).

This display shows positions of aircraft on final approach, landing, and takeoff.

(5) Pictorial Display (Airport Control Area).

This display shows positions of aircraft in flight in the Airport Control Area.

(6) Runway Control Equipment.

This equipment provides the necessary controls to issue clearances for landings and takeoffs such that safe separation is always maintained. Controls to stop the flow to the runway and to divert the inbound traffic are provided.

(7) Voice communication with other Control Areas and aircraft is provided

g. Intercommunication Equipment (Equipment #9 of Figure No. 1). This equipment includes interphone, teletype, microwave and coaxial cable point-to-point relay circuits. These circuits perform the following functions:

(1) Relay traffic and control information between:

(a) General Control Areas.

(b) General Control Areas and Airport Control Areas.

(c) Traffic Data Relay Equipments and General and Airport Control Areas.

(d) Navigation facilities and General and Airport Control Areas.

(e) hfonitoring facilities and General and Airport Control Areas.

(f) Such combinations of the foregoing as IS required.

D. NARRATIVE DESCRIPTION OF AIR TRAFFIC CONTROL SYSTEM OPERATION

In order that the various equipment functions shown on Figure No. 1 may be more easily understood, the following is an example of how these facilities would be used for traffic control during a typical flight. The operational procedures are purposely over-simplified. It is assumed that the origin and the destination are located in adjacent General Control Areas.

In each General Control Area, information is received from other General Areas concerning airport capacities and routes to be used. Each General Control Area analyzes tho prevailing and expected traffic densities and, from this analysis establishes the acceptance rates for its area and forwards this information to other General Areas. These established acceptances are inserted in Airport Time Utilization Equipment (4(d)).

The **pilot's** proposed flight plan may be submitted at the Operations Office. It will be transmitted to the General Area Office by inter-phone and, in some cases, teletype. The flight plan may **be** sent from the aircraft by radiotelephone to the tower or communications facility for forwarding to the General Area Office by interphone and teletype.

Upon receipt of the flight plan in the General Control Area Office of origin, certain items are sent to the General Control Area Office of destination for purposes of obtaining an acceptance time clearance. At the destination General Control Area Office, this clearance request enters the destination's Airport Time Utilization Equipment, and the resulting reserved time is transmitted back to the origin. The reservation is recorded on the General Planning Display (4(f)). Thus, a specific time isallocated which, if no irregularity interrupts the normal traffic flow, will permit an aircraft to land without being delayed by control. *

At the General Control Area Office of origin, the landing acceptance time associated with a specific trip is converted to obtain a desired takeoff time. This desired takeoff time and the acceptance time at the Terminal Area of destination are furnished to the pilot through the radiotelephone link associated with the Landing Navigation Equipment (6b).

The pilot is given taxi information by the Airport Area Office which, for this purpose, utilizes **the** private line channel of equipment (3). This equipment is continuously used throughout the flight. Its other applications will be mentioned later. It is a radio link connected with Traffic Control Equipment (1) in the aircraft which automatically operates indicator signals in the pilot's cockpit.

The routing requested in the pilot's flight plan is checked by the Flight Path Planning Equipment **(4c) and** revised as necessary to conform to the most efficient flow pattern. The Flow Control Equipment (4b) **then** issues specific takeoff clearance automatically, thus providing the pilot with **step-by-step** route guidance out of the Terminal Area of origin. This outbound clearance goes **through the Airspace** Separation Equipment (4a) for safety check and is transmitted to the pilot over **the** private line visual communication link.

During takeoff, the pilot uses the appropriate course generated by the Landing Navigation Equipment (6b). He receives this navigational information via his Navigation Equipment (2) and ILS indicator (2c).

In the air and enroute, the pilot follows the navigational indications produced by his Navigation Equipment (2) which now derives its information from the **Nav-Aid** Equipment (5). This navigational information is in terms of distance and bearing. By means of a computer in the Navigation Equipment, parallel paths are **available,** and the pilot flies that path called for by his flight plan or **the** flight path as revised by the Flight Path Planning Equipment. At all times, his identity and three-dimensional air-derived position are reported automatically via the private line portion of the Traffic Control Equipment.

In those areas where the full system is in operation, the Traffic Control Equipment (1) is interrogated continuously by the Secondary Radar portion of the Traffic Data Relay Equipment (3). These two types of position information are checked in the ground equipment and significant deviations are reported to the control personnel and sent to the pilot over the private line portion of the Traffic Data Relay Equipment to warn him when his navigational information is not reliable.

The positional information enters the Automatic Air Traffic Control Equipment (4). The Airspace Separation Equipment insures safe separation. **If** two aircraft desire to enter the same **block of airspace,** one is permitted to enter and the other is automatically warned that entry is unsafe, This equipment also prevents aircraft from entering any airspace in which fixed obstacles. such as buildings or mountains, constitute a hazard.

Anywhere in the System, the pilot can request limited changes in his traffic control clearance automatically **by depressing code buttons** associated with the symbolic display of the Traffic Control Equipment (1). The request is transmitted on the private line channel of this equipment. It is received by the Traffic Data Relay Equipment and **relayed** for display before the operators in the General Control Area or Airport Control Area offices or it may enter the automatic Traffic Control Equipment directly and receive automatic reply without human intervention.

As the aircraft approaches the Terminal Area of destination, the Flow Control Equipment makes **a** periodic comparison of the aircraft's position with its originally scheduled acceptance time or a later revision of this acceptance time and advises the pilot over the private line the number of minutes he is ahead or behind the desired acceptance time.

Detail Flow Control also plays an increasingly active part as the aircraft approaches the Termi. nal Area of destination. The Flow Control Equipment acts automatically to channel and sequence aircraft to expedite the flow of traffic through the pattern established by the Flight Path Planning Equipment. All clearances originating in the Detail Flow Control Unit are transmitted through the Airspace Separation Equipment for safety check and then to the pilot over the private line visual communication link.

Throughout the entire System, from takeoff to landing, human controllers may override the Automatic Control Equipment as necessary to handle emergencies, special priorities, and other irregularities. For this operation, the Detail Flow Control Unit **uses** the Detail Flow Control Display (4e). Airport Control uses the Symbolic Display (8a) and Pictorial Display (8e). Such over-control must alsd be checked and approved for safety by the Airspac e Separation Equipment.

As the aircraft approaches the Airport Control Area, the operator there is advised **by** data from **the** Automatic Air Traffic Control Equipment. These data appear **on** the Symbolic Display (8a) which shows the identity of the aircraft, and its expected time of arrival. When the aircraft is within the Terminal Area, it also appears in the appropriate layer of the Pictorial Display (8e).

The Enroute or Terminal Area Display (8e) is passed on to the picture modifier. Here portions of the picture, such as traffic at other altitudes, is removed and additional data, **such as** weather tnformation and the operationally desirable tracks, are added. By **use** of the Nav-Aid Equipment, **the** situation picture is then sent to the aircraft, thus apprising the pilot of the traffic situation that exists in his vicinity.

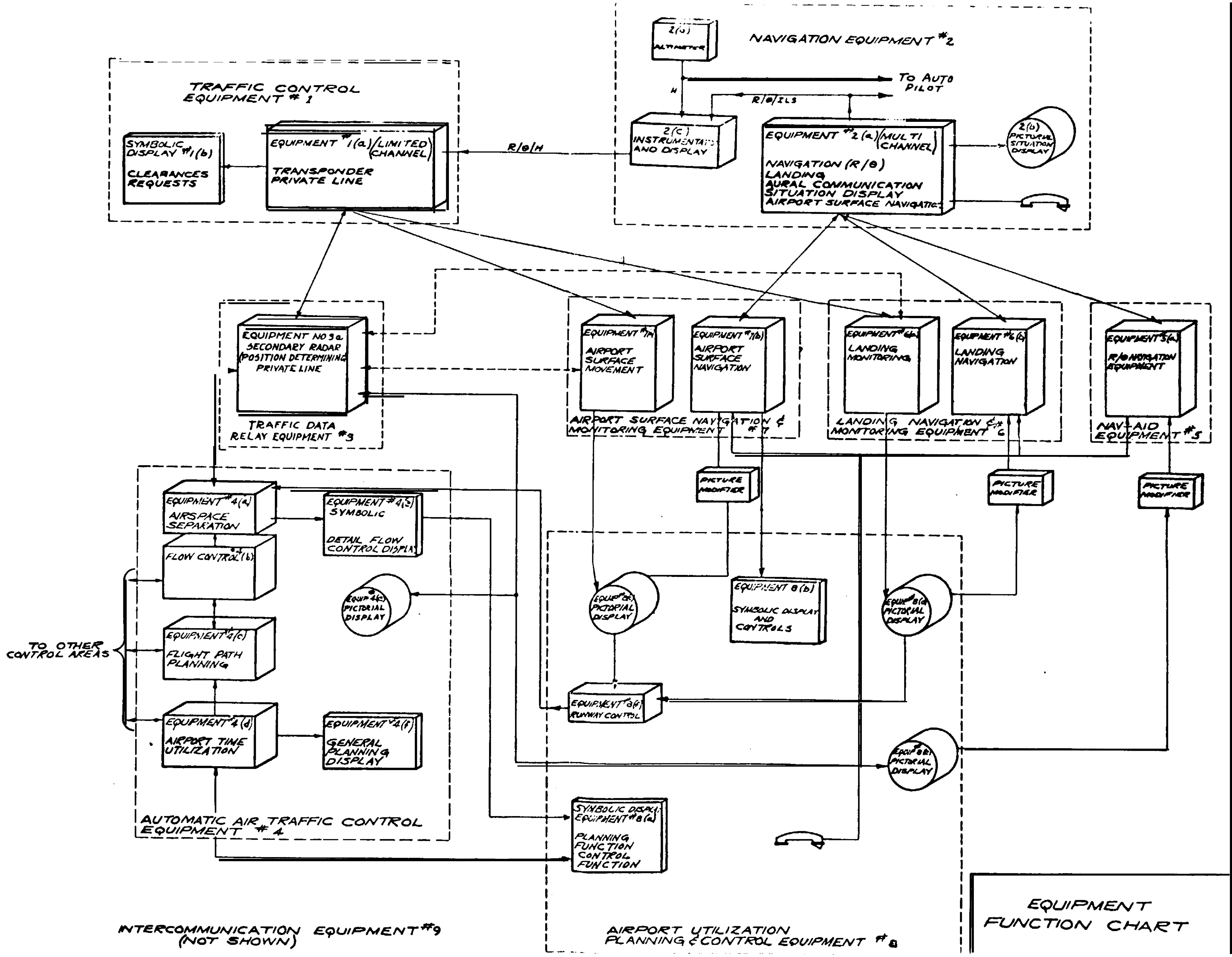
The indications necessary to guide the aircraft to the Final Approach Gate at the instant required to place it in precise time relationship behind the aircraft ahead are transmitted to the aircraft over the private line visual communication link.

The aircraft is flown either automatically or manually down the Final Approach Path generated **by** the Landing Navigation Equipment **(6b).** The Final Approach and Landing operation is monitored **by the** Landing Operator in the airport area office who watches the Pictorial Display (8d) derived from the Landing Monitoring Equipment (6a). The landing display is made brighter and clearer by **the response** of the transponder portion of the Traffic Control Equipment. If additional information must be given to the aircraft during the Final Approach, it may be sent by voice via the aural channel **nel** of the Landing Navigation Equipment, automatically **by** the private line channel of the Traffic Data Relay Equipment, or it can be incorporated in the pictorial landing display which is sent to the aircraft.

Safe separation between landing aircraft **and** aircraft taking off or taxiing is assured by the Runway Control Equipment (8f) which provides an interlock between these functions, If the runway is **not** clear, final landing clearance is automatically withheld, and the aircrsit is diverted over the runway.

As soon as the aircraft is on the **surface** of the airport, it is seen on the Pictorial Display (8c) of **the** Airport **Surface** Movement Equipment (7a).

The Airport Area Operator gives the piIot taxi clearances via the means previously mentioned in connection with taxiing for takeoff, and the pilot taxis, using the Airport Surface Navigation Equipment (7b).



EQUIPMENT FUNCTION CHART

SECTION III

A. EQUIPMENTS OF THE TRANSITION PERIOD

Immediate action must be taken to provide and utilize known air navigation aids and Air Traffic Control equipments which will assist in moving air traffic more safely and efficiently. The following recommendations regarding a program to implement an interim system are made to cover a period from the present time to the time when elements of the "target" system will become available for operational use. Reference is made to Figures 2(A) and 2(B) which chart the development, testing, and utilization time periods involved in the evolution of the final system.

1. Low/Medium Frequency Facilities 200 - 400 Kiloycles

a. Radio Ranges (Four Course)

In the interest of reliability and safety under all weather conditions, there is an urgent need for early transition to static-free radio navigation aids. For this reason, it is recommended that LF Four-Course Radio Ranges be replaced as soon as it is operationally practicable to do so. Operational practicability is not considered as having been attained until a low-cost, light-weight VHF navigation-communication receiver (discussed under paragraph 2(b) of this section) is available.

While the LF range decommissioning period is in progress, it is important that those ranges which remain in service be maintained to existing standards and that judicious selection of frequency assignments be made so that mutual interference will be decreased between the stations which remain in commission.

2. Very High Frequency Facilities

a. Omni-directional Radio Range (Ground)

The VHF omni-directional type radio range is a desirable static-free air navigational aid. However, it is pointed out that extensive re-siting of facilities must bc accomplished if the system is to become progressively of greater value to aeronautical operations. During the transition period when both LF ranges and VHF omni-directional radio ranges will be used during this period, the relative siting of the facilities is of critical importance to Air Traffic Control. As presently located, the simultaneous operation of LF and VOR ranges will complicate Air Traffic Control procedures and, in high density areas, overload air traffic controllers, thereby impeding traffic flow and increasing hazard. It will be necessary to re-site some of these VHF ranges so that aircraft may use either facility during the interim period without crossing or interfering flight paths.

In addition to the foregoing comments, it is recognized that the performance of the present VHF omni-directional radio range is capable of being improved, and it is recommended that development to secure improved operational characteristics be continued during the interim period. Such development should not delay its operational use.

In certain areas, where the very large number of courses obtained with the VHF omni-directional radio range is not required and a more accurately defined air lane is necessary, the use of a two-course VHF facility is recommended.

It appears necessary that the frequency spacing of VHF ranges be 100 kilocycles to accommodate the required number of range facilities in the allocated band.

b. VHF Navigation-Communication Receiver (Airborne)

Models of a producible navigation receiver have been given limited service tests, and airline orders have been placed for a considerable quantity. Initial deliveries are expected shortly. Purchase orders have been placed by the military for small quantities for test purposes. It is estimated that final military specifications for a production model will be available by November 1, 1948. This program should be pursued with all possible vigor as being a partial answer to the pressing navigation problem.

A serious deficiency in this program is the lack cf a suitable low-cost, low-weight navigation receiver for light aircraft. Tentative specifications have been prepared by CXA for a low-priced receiver for private fliers but, to date, doubts as to the potential market have dampened the enthusiasm of interested manufacturers. The only way seen to break this deadlock is to subsidize the development of such a receiver, even in advance of an assured market. It is believed that the development of **such a unit** would create a potential market for this equipment by adding substantially to the utility of personal aircraft.

c. Instrument Landing Systems (Ground)

There was considerable deliberation in attempting to combine the requirements of the several types of aircraft in regard to instrument landing systems. It was agreed that for certain types of scheduled, non-scheduled, and military aircraft the present ILS is satisfactory; however, all other aircraft, including certain military types, could not avail themselves of ILS service. Precision beam radar renders the most service for these types. Also considered was the fact that approximately 500% more ILS than precision beam radar equipments were purchased during the war. Further, it was agreed that ILS and precision beam radar, when used by aircraft equipped to do so, are complementary and, when used together, furnish the most dependable landing information. In view of the foregoing, a complete instrument landing system is considered to consist of five elements. These elements together with recommendations pertaining to each are as follows:

(1) Precision Beam Radar:

It is recommended that an immediate program be initiated to install precision beam radar equipment at all suitable airports where operational requiretnents justify. The allocation of these equipments shall be determined by the Steering Committee discussed in paragraph D3 of this section.

(2) UHF Glide Path Equipment:

It is recommended that the UHF glide path equipment now on order and that in existence be installed on a high priority basis. Allocation of these equipments and **any** additional equipment, as may be required, shall be determined by the Steering Committee discussed in paragraph D3 of this section.

(3) VHF Localizer:

The same recommendations made in the foregoing for the UHF glide path equipment also apply to the VHF localizer, but it is further recommended that the contemplated modification of localizers from amplitude modulation to phase type of modula**tion be** reassessed in view of its international implications and its effect upon United States military utilization of the system. It is recommended that an appropriately constituted committee be established to resolve this problem.

(4) Markers (75 MC) Instrument Landing:

Three markers should be installed with each glide path-localizer installation. These should be kept in operation until they can be replaced with markers operating in the band above 960 Mc. and integrated into the target system.

(5) Low-Medium Frequency Locator Stations (Ground):

Locator stations are a valuable interim aid for use with instrument landing sys**tems.** When **used** with airborne automatic direction finders **(ADF),** these locator sta**tions** provide directional indication and spot position information. Locator stations **are** installed on the localizer course at the middle and outer markers **of** the instrument landing systems. Where frequency allocations will permit, two locator stations should be installed in conjunction with each instrument landing **system.**

It is recommended that the low frequency channels released by the decommissioning of the radio ranges be reassigned to the locator stations.

d. Glide Path Receiver (20 Channel - Airborne)

Preparation **of** a **final** specification should be started at once. Development of the circuits has been completed.

VHF Communication Equipment - Transmitter/Receiver (Ground and Airborne)

To increase cfiiciency in communication between aircraft and ground, it is necessary that all VHF Communication Programs be completed as early as possible.

The VHF ground equipment necessary to meet present requirements is installed. To make this equipment effective, additional airborne equipment is required. To meet certain spe rcquircments, both domestic and international, the purchase of additional ground equipment is necessary.

Existing difficulties with aural voice communications in Air Traffic Control will be materially decreased when the complete changeover to VHF/UHF communications has been completed.

In order to further the utility of the emergency frequency established in RTCA's VHF communication plan, it is recommended that the design of a light, simple, single channel receiver for this purpose be expedited for those users who wish to avail themselves of this service.

f. Fan and Cone Markers - 75 MC (Ground)

These facilities are used by aircraft to obtain spot position information. They must be retained until continuous distance measuring equipment and associated markers are in general use. However, Fan and Cone (Z) 75 MC. Marker Facilities are not considered adequate fur positive position fixing. The indications are not available for a sufficient portion of a flight, the accuracy is often inadequate, and there is no positive means for either the pilot or the Ground Control Agency to determine the technical condition of the system elements during routine operational utilization.

Marker facilities are needed in the "target" system for checking airborne distance indicating equipment, for airport boundary marking on runway center-lines, and as a service to aircraft having partially inoperative equipment. These marker facilities, however, are integrated with the "target" system and are to be provided in a frequency band above 960 Mc.

. Automatic Direction Finding Equipment for Airport Towers

Since VHF communication is the new operational standard, there is a real need for VHF (ground) ADF equipment as an aid to Air Traffic Control.

VHF ADF indication when presented on the same indicator as surveillance radar information can be of valuable assistance in overcoming the identification problem which exists in the use of surveillance primary radar.

VHF ADF when operated by itself can provide valuable assistance to Traffic Control and should be utilized at all airports, especially those at which surveillance radar is not installed.

It is. therefore, recommended that VHF ADF equipment be installed in all airport control towers equipped with surveillance primary radars and in such other Air Traffic Control facilities where the density of traffic warrants.

VHF ADF equipment that the Air Force has had developed appears to fulfill the opera-!. that rcquircmcnt. Operational testing should be started immediately.

Distance Measuring Equipment (Ground and Airborne)

With each VOR (VHF Omni-directional Radio) Range and ILS (Instrument Landing System), there is a need for associated distance measuring equipment in order to provide complete plan position fixing.

At the present time the measurement of distance by radio means has been demonstrat-! Two techniques for'obtaining the required operating channels have been developed. Immediate problem is to determine the technical characteristics of the equipment so ~definite specification can be written. An RTCA Committee (SC40) has been set up to [illegible] the testing procedures and agencies to carry out these tests in order that the techniques developed **can** be evaluated. Decisions on the technical characteristics should be reached in the shortest possible time and, in no case, delayed beyond October 1, 1918. A production specification should **then** be written so that production orders can **be** placed at an early date.

A distance measuring system for interim use should be placed into operation as soon **as** practicable since the lack of distance information in the cockpit is a major navigational weakness at the present time.

Additionally, consideration should be given to the development of a low-priced, light-weight, distance measuring equipment and computer for use in private aircraft so that the private pilot can utilize fully the navigational facilities provided by DME.

i. Offset Course Computer (Airborne)

The development of the offset course computer is nearing its finai phase and should be completed so that at least an interim solution of the navigation problem can be effected at the earliest practicable date.

3. <u>Radar Facilities</u>

a. Surveillance Radar for Terminal Area Coverage - For Airport Control Area Offices (Ground)

An extensive program of surveillance radar installations for airport terminal area use must be inaugurated for purposes of adequate Traffic Control.

Terminal radars of high definition having a dependable operational range on all air-craft of at least 30 miles at all altitudes between 1,000 and 10,000 feet are needed. These radars must contain an MTI (Moving Target Indicator) System and be capable of indicating **range** out to a distance of 60 miles.

The cathode-ray tube displays in the Airport Control Area Offices **and** in the Air Traffic Control Centers should be suitable for daylight viewing. For aid in planning and interpreting traffic movements, a map-like presentation of the controlled area should be provided on the display.

These surveillance radars will obviate the necessity for providing :he surveillance **radars** which are now furnished as part of the Ground Control Approach (GCA) System.

Surveillance radar for Terminal Areas should be installed at all airports where the traffic densities and operational requirements justify.

b. Surveillance Radar, Long Range, for Enroute Operations (Ground)

(1) Installations of long range radars for long range surveillance are being tested at New York; Washington; and Gander Lake, Newfoundland, to determine the extent of their **values** and to develop operational procedures. It is recommended that these installa**tions** be <u>vigorously</u> supported because of their potential value in pointing the way to**ward a** solution to some of the procedural problems of Air Traffic Control.

(2) However, since no clear-cut operational plans have been developed for Airway Surveil**lance,** and since the initial and operating costs are very large, it is recommended that no further airway surveillance radar installations be made until the results obtained with the installations in paragraph (1) **above** have been analyzed.

(3) It is recognized that National Defense will require a system of radar surveillance for **air** warning, and it is recommended that the requirement for airway radar surveillance be coordinated therewith.

c. Airborne Transponder

Rather extensive development is required to perfect altitude coding of the transpondar and to provide the required high accuracy. Consequently, a development program is necessary before quantity production is begun. The urgent need for a transponder, particularly **by the** military services, may necessitate, in the immediate future, the limited procurement of a simplified transponder with simple identity **but** without altitude coding.

Development contracts for small quantities of the interim transponder should be pursued as soon as appropriate decisions on its design can be reached by SC41 - Implemcntation of Air Traffic Control Transpondkr-Private Line Visual Communication Equipment.

d. Secondary Radar (Ground)

It is envisaged that the simplified airborne transponder will be interrogated by ground radars of various types. An "L" band fixed frequency receiver and its associated antenna must be added to each interrogating radar to receive the transponder reply.

Pending decisions by SC41, a development contract should be let to obtain a small number of these receivers to use in operational tests.

4. Communications - Ground

ATC Interphone Circuits (Long Distance Private Line)

In order to provide an improved grade of traffic control service, it is essential that private line circuits with no intermediate "drops" be made available between Air Traffic Control centers. No development is required; however, expansion in number and improvement in circuit quality is essential.

It is recommended that an expansion program be undertaken immediately.

5. Ground Beacons and Airborne Radar

Airborne search radar, when **used** without ground beacons, is considered to have value as a supplementary navigational aid. This value will vary greatly with the type of terrain. The use of ground beacons in conjunction with airborne radar increases the value of airborne radar as a navigational aid and makes its navigational information less dependent upon terrain features and pilot experience.

The cost and weight of equipment and the difficulty of carrying duplicate equipment, particularly the antenna installation, make it impractical to consider airborne radar as the primary navigational aid. It is recommended that installations of the best available ground beacons be made to serve those military and commercial aircraft which carry airborne radar.

The use of airborne radar for air to air collision warning is considered to be of small initial value to traffic control and flying safety. Airborne radar in this connection is expected to show slowly expanding value for special uses, particularly as airborne beacons come into general use. **The** use of airborne radar for this purpose, however, is not considered of sufficient importance to have any large effect upon the Traffic Control problem in the interim period.

It is anticipated that actual installation of airborne radars in military and commercial aircraft will be made for purposes other than navigation and collision prevention; namely, for the avoidance of collision with terrain, the avoidance of dangerous weather, and to meet tactical requirements.

6. Electra-Mechanical Devices (Ground)

a. Mechanical Interlocks

Operational trials have been in progress in the New York area for some time on a form of this equipment. It is urged that a production specification be written and procurement started immediately so that operational equipments can be in use at other major terminals in as short a time as practicable.

b. Approach Control Timing Equipment

This equipment has been in operation at New York for some time. A production specification should be written based on the results of the experience gained in New York and other control areas. Production equipments should be available for use at certain major terminals in 1 - 2 years after writing of the final specification.

c. Airport Time Utilization Equipmt It

Operational requirements are known, and methods of implementation have been demonstrated. Preparation of the final development specification should be started at once.

Equipment can be made available for service use one year after the placing of a dcvelopment contract provided such equipment is found to be required by existing traffic densities.

7. Test Equipment

Coincident with the start of the research and development program for the foregoing equipment, there should be initiated a similar program for the design of a complete set of test equipment. Such a program should include the preparation of the necessary training materiai to provide a set of standard testing methods and procedures for use by maintenance personnel. Emphasis should be directed towards getting the test equipment delivered to the users at the same time or earlier than the operational equipment.

a. Non-Electronic Developments and Improvements

a. Obstruction Clearance

It is recognized that some airports will require two or more instrument landing installations in order to provide service for two or more wind directions. The principal impediment to such a program is apt to be the existence of only one approach adequately free of obstructions at many important airports. Consequently, emphasis must be given to the problem of removing obstructions where such action is feasible.

b. Other Non-Radio Aids

The recommendations made in the foregoing pertain to the radio-electronic solutions of the Traffic Control Navigational problem. It is recommended that this material be supplemented by solutions worked out by others and relating to such non-radio aspects of the problem as:

(1) Improved airport design.

(2) Runuay and Approach Lighting.

(3) Fog dispersal systems.

(4) Improvement in the ratio--cruising speed/approach speed--of aircraft.

B. EVOLUTION OF THE OPERATIONAL USE OF THE EQUIPMENT

SUMMARY OF PRESENT TRAFFIC CONTROL PRINCIPLES AND PRACTICES

Air Traffic Control is accomplished at the present time by the use of standard operating procedures based on the Civil Air Regulations.

Airport Traffic Control and Airway Traffic Control cooperate to provide the complete service.

1. Airport Traffic Control service is provided by operators, usually located in control towers, who observe the approach and departure paths: as well as the surface of the airport. The operations are separated into takeoff and approach control and airport surface traffic control.

Control Tower Operators:

a. Issue clearances for taxiing, departing, approaching, and landing,

b. Advise pilots concerning flight restrictions. field conditions, weather conditions, navigationnl aids, and emergency conditions,

c. Relay traffic messages between pilots. operations offices, route control centers, weather offices, and communications stations, and

,\i.t,~~ltc emergency measures when an emergency occurs either in the vicinity of or on the airport

Airway Control provides service within prescribed areas on the United States Civil Airways .! ›n certain air routes used in International Operations. Each area contains about 2000 miles ‹ airways and is usually controlled from a center (ATC) located at the largest terminal within ‚ . area Within the center, the work load is divided on the basis of geographic sectors.

Airway Cont rollers:

a. Issue clearances which include acceptance times, altitudes, routes, holding information, and speeds desired for traffic control,

b. Advise pilots concerning hazards,

c. Sueggest changes in flight plan,

d. Provide other information which may be helpful in maintaining safe and expeditious flight,

e. Maintain a log based on aircraft position reports,

f. Initiate action to locate overdue aircraft,

g. Assist aircraft which are having difficulty, and

h. Report aircraft accidents.

Pilots, under instrument conditions, are required by Civil Air Regulations to:

i. Submit a proposed flight plan,

j Comply with clearances,

k Make position reports, **and**

l. File an arrival notice.

; The following minimums are in effect:

a Vertical - 1000 feet separation between air lane centers: 500 foot separation as determined by the altimeter in aircraft is permitted in emergencies.

b. Longitudinal - Ten minutes separation is standard for aircraft having similar speed characteristics. To avoid overtaking, greater separation is used when speed characteristics differ widely. Minimums for departing, ascending, and descending aircraft vary with prescribed conditions.

c. Lateral - No fixed lateral separation minimums are in effect. Opposing traffic is laterally separated by right side separation along low frequency radio range courses. Safe operation requires that lateral separation be used to separate ascending or descending traffic from “through” traffic. Lateral separation based on low frequency radio range navigation is hazardous because of convergence at the facility and because of low accuracy **in the** quadrants.

Rapid and reliable communication circuits are essential to Air Traffic Control. At the present time, interphone circuits carry clearances, position reports, acceptance time data, and information involved in the coordination between air route control centers, towers, communication stations, **and** operations offices.

Teletype is used **for** the transmission of flight plans, the checking of overdue aircraft, etc.

Aural (voice) radio circuits handle communication between aircraft **and** ground stations. these circuits are in the low, medium, high. and very high radio frequency bands; the circuits used **depend** upon the type **of** airborne equipment carried.

Geographic spot position reports to the Controller are made by the pilot at navigational **aid sites** and at designated "fixes" such as the intersections of range courses.

6. Procedures are in effect to avoid saturation of certain terminal areas; however, they are not uniform for all areas, and improvement is required.

7. Meteorological service is provided by weather forecasters at air route traffic control centers.

CAUSES OF OPERATIONAL BREAKDOWN AND RECOMMENDATIONS FOR IMPROVEMENT

Present Traffic Control is based upon the utilization of equipment and systems which were not intended for the purpose. In fact, there is no electronic equipment specifically designed as an aid to Air Traffic Control. This condition, plus the inadequacy of existing navigational aids, produces most of the difficulties discussed below.

Electronic aids alone cannot provide a suitable solution to the Air Traffic Control problem. Terminal conditions and traffic control procedures also must be materially improved.

1. Terminal Conditions

a. Takeoff delays can be substantially reduced by increasing the width of taxi strips and by placing them so that entry to and exit from the "live runway" can be accomplished more expeditiously.

b. Too frequently, the choice of airport sites has been made with little or no consideration for **the** requirements of Traffic Control. Conflicts between approach and departure paths often restrict operations to such an extent that the capacity, under certain conditions, of two ad**jacent** airports is no greater than that of one of them **alone.**

2. ATC Procedures

a. Congestion in the Terminal Area decreases the safety and expeditiousness of flight operations. Flow control procedures now in effect require that the terminal controller contact controllers in adjacent areas acd have them stop, or limit, the air traffic.

It is recommended that more efficient flow control procedures be established to limit **the** quantity of aircraft in a Terminal Area to that which the system and the runways can **safely** and expeditiously accommodate.

b. Present Air Traffic Control procedures are of such complexity that considerable training **of both** pilots and controllers is necessary. Lack of familiarity with procedures is a prevalent cause of inefficiency The training programs should **be** supported, and special em**phasis** should be directed toward training aids **for** those pilots who are not employed by organizations having training standards and programs.

c. A limited number of standard flight paths should be established at all airports where feasi**ble.** This will simplify flight procedures and will enable pilots to gain valuable experience **through** repetition. Flexibility **of** overall control should be maintained by authorizing the use of non-standard flight paths when required by operating conditions.

.d. Attention **must** be directed toward reducing the burden on traffic controllers by providing **them** with improved manual interlocks and simplified coordination procedures.

3. Electronic Aids

Enroute - Using present navigationalaids, the pilot isable to make only infrequent geo**graphic** spot position reports. These are often inaccurate at the time of report or are de**layed** in transit and, therefore, are inaccurate **by** the distance travelled during the delay in**terval.**

Many of the delays and interruptions to smooth traffic flow result either from the pilot becoming lost or from the controller losing track of the aircraft's position or identity. When the controller knows that an aircraft is in a high density area, and lacks either its position or its identity, an emergency situation develops which can and does produce large delays in the movement of traffic.

4. Terminal Area

Inefficient spacing of aircraft on Final Approach is a serious cause of delays.

The deficiencies mentioned above can be substantially overcome by the expanded operational use of aids which are now available or which can become available in the near future.

The enroute problem can be improved by the use of VHF Omni-directional radio ranges (VOR), Distance Measuring Equipment (DME), and Offset Course Computer. The terminal situation can be bettered by extensive operational use of Surveillance Radar, VHF/UHF Instrument Landing facilities (ILS) combined with Precision Beam Radar (GCA), and VHF Automatic Direction Finding.

In addition to the above, there is an urgent requirement for the full implementation of the VHF communication plan. Many aircraft are stilt using communication equipment in the LF-HF radio frequency bands where atmospheric and precipitation static can delay or interrupt the flow of clearance data, position data, and other information essential to Traffic Control. VHF communication equipments which overcome the weather difficulty are coming into more general use and should be in operation in all aircraft.

In high density areas, Air Traffic Control requires one VHF channel for airport surface traffic and two channels for communication with aircraft in the vicinity of the airport. These are furnished by:

a. The Voice Channel of the ILS

b. An Airport Area Control Office Channel

c. An Airport Utility Channel

Point-to-point communication on the ground is deficient because of an inadequate number of direct interphone circuits between air route traffic control centers. This causes a deterioration in coordination between centers. However, no substantial help will be given to the handling of larger volumes of traffic, both enroute and onto the landing runways, until the controller is relieved of most of the manual coordination job by the use of automatic air traffic aids and until the "bottlenecks" associated with aural (voice) communication are eliminated.

IMPROVEMENT OF TRAFFIC CONTROL AS ELEMENTS OF "TARGET" SYSTEM BECOME AVAILABLE

The foregoing implementation fails to provide air and ground personnel with relief from the problems associated with the utilization of non-automatic aural radiocommunication. It also does not provide adequate data to traffic control concerning the locations of aircraft in the controlled airspace.

Introduction of the secondary radar interrogator-transponder and the private line radiocommunication elements of the Target System is essential to safe and expeditious aircraft operations, and they can 'provide substantially improved traffic control prior to their utilization in the essentially automatic "target" system.

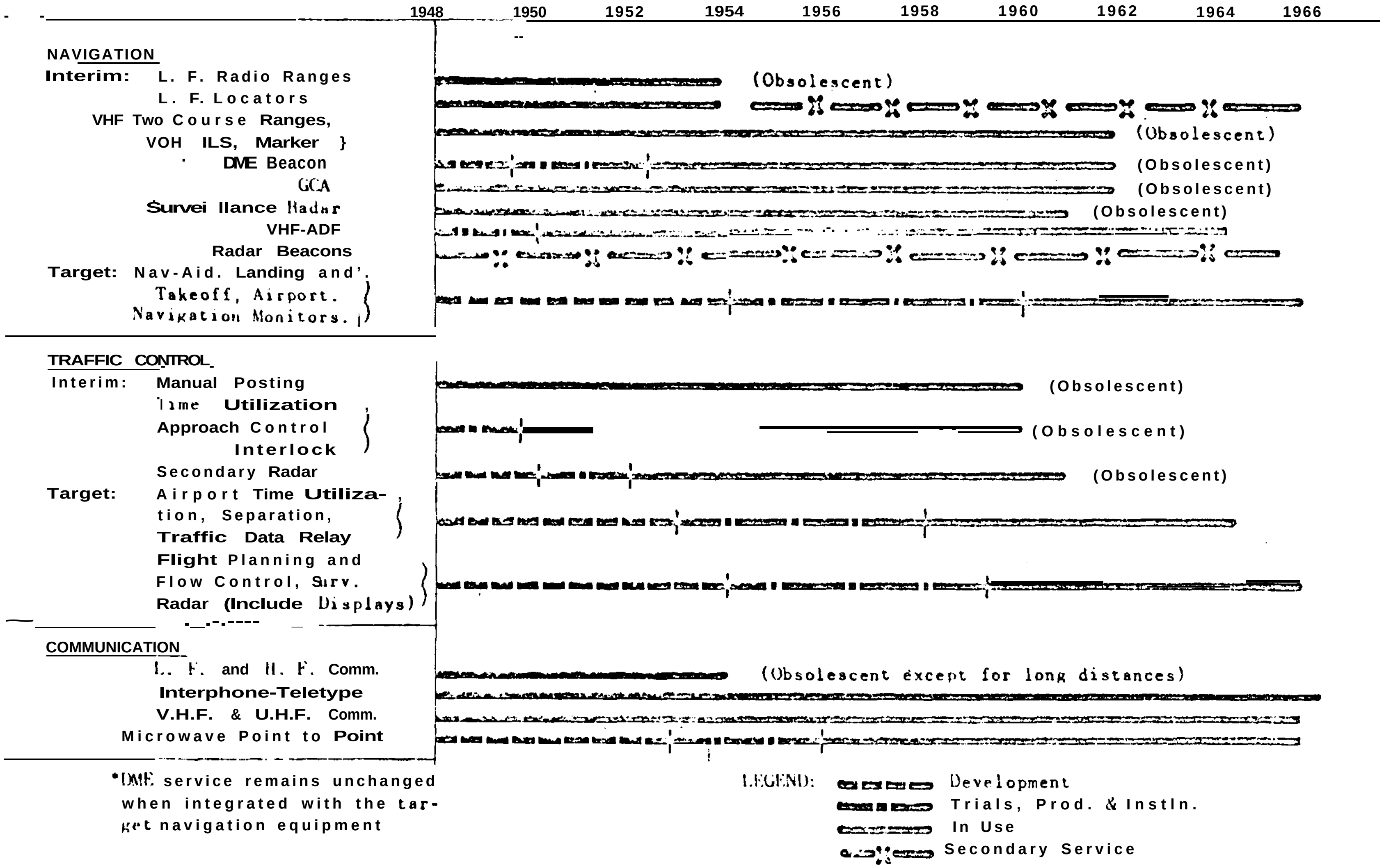
In the development of the overall Traffic Control System, major technical emphasis must be placed upon the solution to the private line visual indicating radiocommunication system, since this portion of the overall system is the key element in obtaining improved Air Traffic Control. This technical emphasis is also required in order to assure full operational utilization of secondary radar interrogator-transponder and the private line systems at about the same time.

Approach Control Timing Equipment, Mechanical Interlocks between General Control Areas and Airport Control Areas, and Airport Time Utilization Equipment when used in conjunction with the operational procedures contained herein can provide improved safety and flow control.

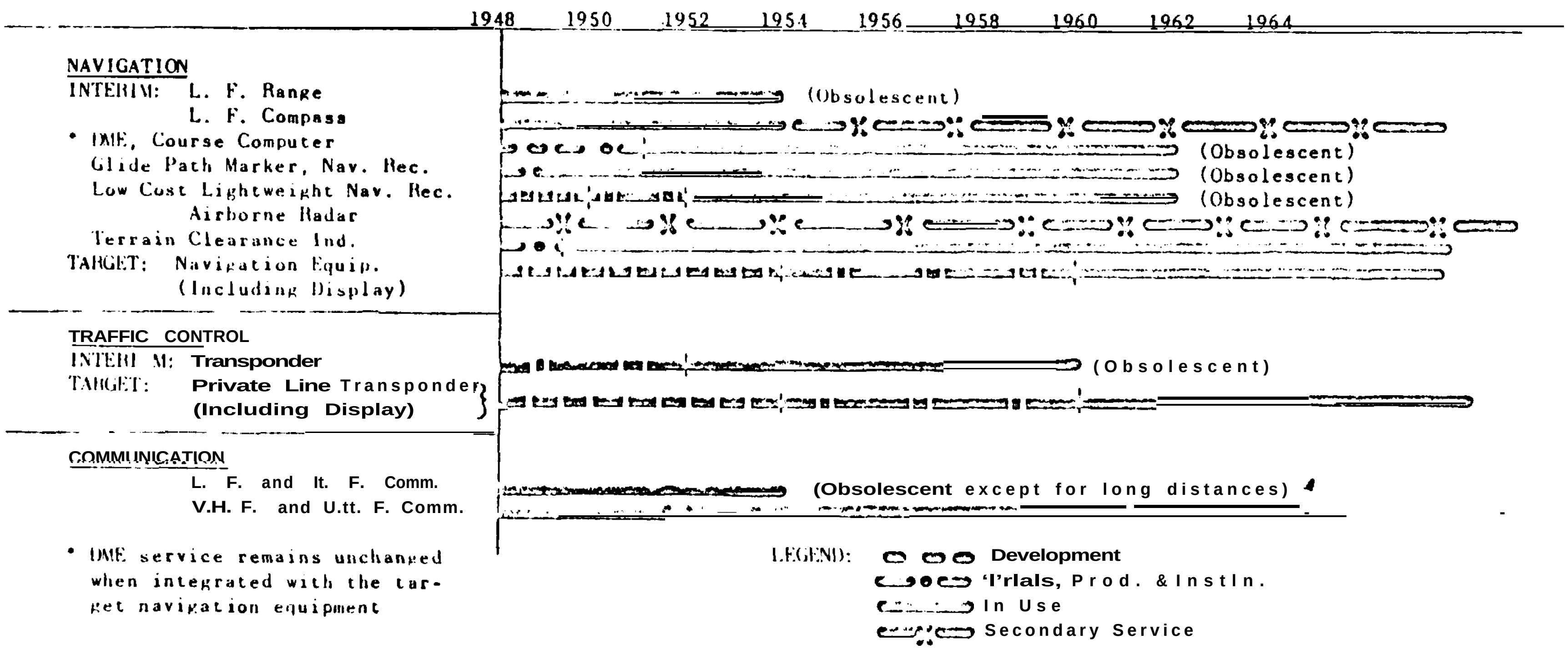
Operational use of these equipments should be hastened, including expansion of such administrative units as Air Traffic Control Centers and Airport Control Towers, and increase in ground point-to-point communication facilities so that early realization of these traffic con-

EVOLUTION CHART OF GROUND EQUIPMENT

Figure No. 2A



EVOLUTION CHART OF AIRBORNE EQUIPMENT   Figure NO. 3



trol improvements can be effected.

Further improvements in safe and expeditious movement of air traffic will come about with the use of the Automatic Air Traffic Control Equipment.

Air Traffic Control during the interim period will be hampered by the lack of an adequate, universally used standard navigation and landing system. In addition, the airport surface navigation and traffic control problem will not differ from present day practice in any essential manner until the adoption of the private line communication system. With the advent of operational utilization of the Nav-Aid Equipment, the Landing Navigation Equipment, and the Airport Surface Navigation Equipment, or any portions thereof, Air Traffic Control can be improved in several significant ways, namely:

a. The integrated airborne navigation equipment will provide service to smaller aircraft which heretofore have lacked complete enroute navigation and landing information.

b. Aircraft, in general, will have more accurate and complete navigation and landing information.

c. Distance information will be available to a larger number of the pilots, and the increased accuracy of navigational aid will permit closer lateral separation of airlanes. A larger number of more suitably spaced airlanes in the enroute and terminal areas will be possible.

   In addition, airborne visually indicated situation information will improve coordination between air and ground personnel.

d. The problem of airport surface traffic navigation and control under conditions of low visibility will be materially bettered by reason of the airport surface movement equipment, the airport surface navigation equipment, improved communications, and improved aids to controllers for display and monitoring.

Generally speaking, any feature of the coordinated navigation and landing program can be implemented as it becomes available and can bring about improvement in the overall Air Traffic Control and Navigation operational situation.

C. INTEGRATION

Evolution toward a completely integrated system in an orderly manner involves a most searching type of analysis and attention to detail. A design characteristic of an interim model of one or more of the critical equipments can easily block the further extension of the system. On the other hand, interim equipments are urgently needed now and cannot be unduly delayed. It is vital that a coordinated program be worked out to obtain interim relief without blocking development of a completely integrated system.

Because aviation has developed so rapidly, all available efforts were needed to solve the immediate problems and consequently there has been little long-term planning directed toward a coordinated system that would give maximum service with minimum weight and complexity.

It is, therefore, recommended that appropriately constituted engineering groups study the problems of airborne equipments and their associated ground elements for the purpose of establishing "standard signals" for the air-ground circuits.

The term "standard signal", as used herein, refers to the detailed manner in which the radio frequency spectrum will be used but does not include detatls of equipment design except by implication within the scope of a specific technique.

The "standard signal" specification shall include:

a. Radio Frequency

   (1) band limits
   (2) number of channels
   (3) bandwidths
   (4) guard bands
   (5) allowable frequency variations

(6) air to ground or ground to air
(7) services to be provided, i.e., aural communications, navigation, etc.

b. Signal modulation requirements

(1) level setting
(2) pulse and/or CW detailed characteristics
(3) synchronization characteristics and/or time sharing features.

c. Transmitting and Receiving pattern features including polarization but not including antenna specification details. However, the polarization employed for any element of the system shall not:

(1) Prevent multiplex operation of other system elements with a common antenna system.

(2) Prevent the attainment of omni-directional coverage.

(3) Require an airborne antenna system which is appreciably detrimental to the performance of high-speed aircraft.

The "standard signal" specification will be a major factor in evaluation of competitive techniques for interim equipments. Since the obsolescence of airborne equipment (and the associated economic and administrative burden on aircraft users) as of a specific deadline date is nearly impossible to administer in a civil aviation system, plans must be made in advance to allow a gradual change from interim to final equipment as it becomes available.

D. ADMINISTRATION

1. The Interim Program

Part A of Section III lists recommendations pertaining to a number of facilities which are already in existence or which can be developed from known techniques. It has been estimated that the implementation of the recommendations of Part A will increase the figure of merit of the Traffic Control System (based on the principles in the first section of this report) from about 40 to 65 per cent and, it Is, therefore, urged that early action be taken so that aid may be given to present air operations.

2. The Long-Term Program

The basic elements of the long-term program were described breifly in Section II. Appendix III gives a detailed description of each of the equipments required for the target system.

In order to bring these equipments into being, considerable research and development is required, and such work should be started immediately. Even if work is started immediately, the target system is not likely to be fully operational until approximately January 1, 1963. This long-term program should be started as soon as funds can be made available. Technical personnel and laboratory facilities are available to prosecute the development program in the time schedule just named. It is estimated that full implementation of the long-term program will bring into being a system with a figure of merit of approximately 95% - a further improvement of 30% over the Interim program.

3. Monitoring The Programs

To assure that continuity is maintatned in implementing the RTCA program for an all-weather air traffic control system, it is recommended that a permanent Air Traffic Control and Navigation Steering Committee be established, to include representation from all users of the airspace.

E. TIME AND COST FACTORS

The following tabulation is a summary of Figures 3-A and 3-B.

TIME AND COST SUMMARY

The Research, Development, Production, and Application Programs assume the existence of a total of approximataly 100,000 equipped aircraft by 1960 (see notes).

1. Research and Development Cost

	1st 3 yrs.	2nd 3 yrs.	To Complete Program	Total
a. interim Program				
(1) Airborne	3.4	---	---	3.4
(2) Ground	2.3	---	_--	2.3
b. Target Program				
(1) Airborne	4.7	6.7	1.6	13.0
(2) Ground	24.1	25.8	6.8	56.7
Total Research and Development Cost	34.5	32.3	8.4	75.4

2. Production and Operational Application Cost

	1st 3 yrs.	2nd 3 yrs.	To Complete Program	Total
a. Interim Program				
(I) Airborne	163.5	28.0	---	191.5
(2) Ground	163.5	14.5	---	178.0
b. Target Program				
(1) Airborne	---	---	169.0	169 .O
(2) Ground	---	64.3	434.6	498.9
Total Production and Application Cost	327.0	106.8	603.6	1037.4

3. Total Cost 1112.8

(Figures are in millions of dollars)

4. Notes For Time and Cost Summarv

a. Air Force, Navy, and Civil Aeronautics Administration expenditures for ground equipment **are** grouped together.

b. For airborne equipment production and operational application, it is estimated that only 40 **per** cent **of** the costs, in both the interim and the ultimate programs, will be borne by **the** government while the balance will be expended by commercial and private groups.

c. Operation and maintenance costs are not included in the Time and Cost Charts, except for wire charges shown in :he supplement.

d. Cost estimates for Long Distance navigation aids and Weather Bureau expenditures are not included.

e. It is assumed that the 100,000 equipped aircraft in 1960 are apportioned as follows:

(1) Military (all kinds) 35,000
(15,000 of these are dual equipped)

(2) Commercial (all kinds) 10,000
(5,000 of these are dua! equipped)

(3) Equipped Private 55,000

f. It is assumed that the Target System ground equipments are apportioned as follows:

(1) Each of 50 General Control Area Offices contains:

(a) Flight Path Planning and Flow Control Equipment

(b) Airport Time Utilization Equipment

(c) General Planning Display

(d) Detail Flow Control Displays (Pictorial and Symbolicl

(2) Each of 550 Airport Control Area Offices contains:

(a) Landing Navigation Equipment

(b) Landing Monitoring Equipment

(c) Airport Surface Navigation Equipment

(d) Airport Surface Movement Equipment

(e) Airport Utilization, Planning, and Control Equipment (including displays).

(3) Each of 550 enroute stations contains:

(a) Traffic Data Relay Equipment

(b) Primary Surveillance Radar used in conjunction with Secondary Radar (may only be required at 400 stations. Additional radars will be required in certain Terminal Areas.)

(c) Airspace Separation Equipment

(d) Nav-Aid Equipment

(4) The point-to-point microwave and/or coaxial cable relay circuits provide for communications over 25,000 miles.

g. If the numbers of aircraft and ground facilities, assumed in Notes e. and f. are found to be inaccurate **in** the future, then the operational application costs shown will have to be **adjusted** accordingly.

5. Supplement To The Time and Cost Summary

The following **are** cost estimates of Interphone and Teletype rentals and Teletype equipment including all necessary circuits for weather data relay.

a. Interphone and Teletype Rentals (C.A.A.)

Wire Charges

Fiscal Years	Interphone Mileage	Interphone Cost/yr.	Teletype Mileage	Teletype Cost/yr.	Total Cost/yr.
1948	48,787	$2,587,536	109,534	$2,211,114	$4,798,650
1949	60,093	3,055,176	118,380	2,391,895	5,447,071
1950	72,093	3,775,176	119,860	2,876,660	6,651,836
1951	73,289	4,397,340	121,340	2,912,160	7,309,500
1952	74,485	4,469,100	122,820	2,947,680	7,416,780
1953	75,680	4,540,080	124,300	2,983,200	7,523,280

b. Teletype Equipment

Fiscal **Years**	Stations to **be added**	**Total cost**
1949	**110**	$404,203
1950 - 53	70	243,000
	180	$647,200

Note: Average of 3 teletypes per station including standbys.

Cost estimates for wire charges after the first five years will remain about the same as for the Fiscal Year 1953 until replaced by point-to-poinl relay circuits.

F. RADIO FREQUENCY SPECTRUM REQUIREMENTS

1. Ideally, the projected system of Air Navigation and Traffic Control should be established in the frequency bands 960-1215 Mcs. and 1300-1600 Mcs. (Note 1). It is believed !hat the two airborne equipments and their ground-air links can operate in this band. However, since it cannot bc stated without qualification that all of the functions required can be accomplished in these bands, investigations must bc carried out to determine the practicability of combining the functions. Certain other functions such as landing monitoring, airport surface movement, position determining, etc., will operate in their allocated bands It is emphasized that the foregoing radio frequency spectrum requirements do not represent the entire frequency requirements of the aviation service.

Frequency Band and Bandwidth MC	Circuit	Function Performed
	Air-Ground	DME, Voice
960 - 1215 (255)	Ground-Air	DME, Voice, Marker, Final Approach and Landing, Azimuth, Situation Display, Airport Surface Navigation (Note 2)
1215 - 1300 (85)		Amateur
1300 - 1365 (65)		Surveillance Radar
1365 - 1660 (295)	Air-Ground	Transponder reply, automatic position reporting including Identity, Private Line (Flow and Occupancy), Secondary Radar Interrogation (Note 3), Altimeters

Note (1) See Appendix IV

Note (2) Airport surface navigation may use a band either higher or lower than this.

Note (3) In order to obtain the azimuth accuracy required, it may be necessary to operate secondary radar interrogation at a higher frequency.

2. The airborne navigation equipment and its directly associated ground elements are wholly contained in the 960 - 1215 MC. band. The azimuth, landing, voice, situation display, and airport surface navigation functions will be multiplexed with the ground to air function of the DME. The air to ground voice circuit will be multiplexed with the air to ground function oi the DME. If research and development reveals that the multiplexing of all **of** these functions is not feasible, either for technical or economic reasons. some of them will be located in other bands allocated to the aviation service.

3. Based upon operational and economic factors associated with the interim utilization of VHF omni-directional ranges, VHF instrument landing systems, and VHF communications, it is necessary that a technical program plan and order of priority exist for the transiticn.

The preferred order from the operational standpoint for implementation of the functions of the target navigation system is as follows:

a. Distance Measuring

b. Marker

c. Landing (azimuth and slope), including air-ground voice

d. Azimuth, including air-ground voice

e. Situation Display

f. Airport Surface Navigation, including two-way voice. (Depending upon the method of implementation, this may require a higher or lower frequency band.)

The situation display (e) may well be the most difficult to integrate after a distance measuring system is in general use. It is desirable that the transition be made without obsoleting equipment which is in use at that time.

4. The airborne traffic control equipment and its directly associated ground elements will operate in the band from 1365 - 1660 Mc. Air Traffic Control functions, including transponder reply, automatic position reporting including identity and private line (flow and occupancy) are multiplexed in this equipment. If it should prove impractical to multiplex all of these functions in this band, they will be located in one of the other bands allocated to the aviation service. Secondary radar will also be integrated with the above equipment. It will operate in the same band unless the necessity for obtaining greater azimuth accuracy furccs it to a higher frequency. The amount of spectrum used for this integrated equipment will be coordinated with. the other functions operating in this bnnd.

5. Primary surveillance radar has been allocated bands between 1300 - 1365 Mc. and 2700 - 2900 Mc. The airborne traffic control equipment will assist these radars.

APPENDIX I

A. OPERATING. PRINCIPLES AND SYSTEM REQUIREMENTS

Operating principles and system requirements vary with operational areas. The specific operating principles and system requirements which are objectives and are applicable to each of these areas are as follows:

1. All Areas

a. The limiting factor in the movement of aircraft through the navigable airspace is the acceptance rate of the Final Approach Area(s) of the Terminal Area(s). It is the objective that this acceptance rate approximate, under all conditions, that possible under CAVU conditions.

b. The basic quality of traffic control service shall be identical to all users. This shall not preclude the use of more convenient or rapid means of traffic control interpretation by any class of aircraft desiring it nor require such means by any user. There shall be only one system of traffic control.

c. Aircraft shall be promptly advised of all factors which affect safety.

d. The Traffic Control System should be such that the pilot will maintain essentially fixed procedures through which he can gain valuable experience by repetition.

e. The System shall relieve human burden by other than human means whenever it may be done without detriment to operations.

f. Information presented to a pilot of an aircraft shall not be ambiguous.

g- The System shall be capable of adaptation to orderly growth and not require radical changes periodically. .

h. The System shall be adaptable to extension to new areas as required by the expansion of aeronautical operations.

i. Modifications of the System to meet future operating requirements shall result in no deterioration in efficiency.

1. The System shall efficiently accommodate changes which result from operational planning.

k. The System shall be capable of furnishing reduced service to aircraft with partially inoperative equipment.

1. The System shall provide immediate and positive indication of malfunctioning of the System and permit continuation of safe flight in the event of such malfunctioning.

m. ‘Identification of, and communication with, aircraft under ground control is essential.

n. Suitable checking procedures shall be established to minimize human errors in any part of the System.

o. All electro-mechanical devices shall incorporate safety features which cannot be overridden in an unsafe manner by a human agency.

p. Electra-mechanical devices shall be provided with suitable interlocks.

2. Airport Taxi Area

a. Separation shall be achieved by lateral and longitudinal separation. Flexibility in separation shall be provided so that aircraft and other vehicles may be accommodated.

b. The rate of clearing the live runway and the rate of supply of aircraft to the live runway shall no! limit the acceptance rate.

c. Surveillance, in addition to normal visual means, shall be provided at all times where traffic density warrants. Surveillance shall operate satisfactorily under all weather conditions.

3. Terminal Area

a. The System shall be so designed that the Terminal Area shall not be an impediment to through traffic.

b. The System shall permit planning the normal operational tracks into, within, and out of the Terminal Area, thereby avoiding, insofar as practicable, the necessity for any on-the-spot solutions of difficult traffic problems by human controllers.

c. The final adjustment of aircraft movements to provide an efficient rate of flow into the Final Approach Area shall be accomplished within the Terminal Area;

d. Authority for limiting the acceptance rate of an airport shall be vested in a terminal area control.

e. The System shall stop or reduce the volume of flow of traffic into and through the Terminal Area when necessary without establishing or maintaining individual voice communications with each aircraft whose flight progress may be affected.

f. Holding shall be accomplished in Terminal Areas primarily-and should not be planned on any airway.

g. In addition to the automatic system, visual display to the controller of aircraft positions shall be presented in a way that permits the controller to take action prior to the incidence of hazardous conditions. The facilities for display should provide an indication which cannot be operationally saturated.

h. The System shall be capable of supplying information to a terminal area control of the progress of aircraft, near or within the Terminal Area, which intend to land so that traffic flow may be adjusted.

Information which may be necessary to a terminal area control includes:

(1) Aircraft identity
(2) Aircraft altitude
(3) Aircraft plan-position
(4) Aircraft destination
(5) Aircraft speed
(6) Time

i Surveillance, in addition to normal visual means, shall be provided at all times where traffic density warrants. Surveillance shall operate satisfactorily under all weather conditions.

j Monitoring of the System shall be provided at all times.

k. In providing lateral separation of aircraft in the Terminal Area, adequate provision is required for aircraft in holding and maneuvering. The system shall not require any aircraft **to bank in excess of 30°.**

4. Final Approach Area (Part of Terminal Area)

a. At the present time, limitations of navigation facilities and other considerations preclude the use of simultaneous approaches on parallel runways of existing airports. The ultimnte system should provide for the simultaneous use of parallel runways at spacings considerably less than 2 miles.

b. Separation shall be achieved by longitudinal spacing. Flexibility in spacing shall be provided so that aircraft of varying speed characteristics may be accommodated.

c. Minimum longitudinal separation in the Final Approach Area may be tentatively considered as $1\frac{1}{2}$ to 2 minutes but ultimately should be equivalent to VFR separation.

d. Terminal Area Control shall designate the live runways and shall vary them to meet operational requirements.

e. The System shall be capable of directing aircraft pull-outs and accommodating intentional or accidental missed approaches of aircraft which had intended to land.

5. Initial Approach Area (Part of Terminal Area)

a. Separation shall be achieved by longitudinal, lateral, and/or vertical separation. Flexibility in separation shall be provided so that aircraft of varying speed characteristics may be accommodated.

b. The System shall not preclude the use of 500 feet vertical separation.

c. Minimum longitudinal separation shall be twice the time separation of the Final Approach Area until adequate and reliable means are available which will permit a decrease in the interval.

d. The System shall permit a minimum lateral separation at any one altitude of 4 miles.

e. A number of flight paths are essential to accommodate aircraft arriving from several directions and to assure an adequate flow of safely spaced aircraft into the Final Approach Area.

f. The System shall include means for controlling the time of arrival of aircraft at the Final Approach Gate by varying flight path lengths and by employing the variable speed characteristtcs of the aircraft under control.

g. The System shall bc capable of accommodating intentional or accidental missed approaches of aircraft which had intended to land.

h. Varying aircraft speeds dictate that flow control and positive separation be provided; such flow control and positive separation shall be achieved by methods eliminating, to the maximum extent possible, the hazard or inefficiency induced by human factors.

6. Holding Areas (Part of Terminal Area)

a. Separation shall bc achieved by vertical separation in each Holding Area.

b. The System shall be capable of accommodating departures of aircraft from the Holding Area at any altitude which will expedite descent to a Final Approach Altitude at the Final Approach Gate.

c. The System shall be capable of accommodating intentional or accidental missed approaches of aircraft which had intended to land by providing space within the Holding Area, if required.

d. Holding shall be achieved by methods eliminatin,, to the maximum extent possible, the hazard or inefficiency induced by human factors.

7. Departure Area (Part of Terminal Area)

a. Separation shall be achieved by longitudinal, lateral, and/or vertical separation. Flexibility in separation shall be provided so that aircraft of varying speed characteristics may be accommodated.

b. The System shall not preclude the use of 500 feet vertical separation.

c. The System shall permit a minimum lateral separation at any one altitude of 4 miles. When simultaneous takeoffs on parallel or tangential runways are authorized, the flight paths of the aircraft shall be divergent until a 4-mile lateral separation is attained.

d. A number of flight paths in several directions are essential to accommodate departing aircraft and to assure an adequate flow of safely spaced aircraft from the live runway.

e. The System shall be capable of accommodatin, intentional or accidental missed approaches of aircraft which had intended to land.

f. A terminal area control shall determine the live runways and shall vary them to meet operational requirements.

g. Responsibility for flight planning with relation to Air Traffic Control shall be by the pilot with the cooperation of, and for approval by, the ground.

8. Enroute Area

a. Separation shall be achieved by longitudinal, lateral, and/or vertical spacing. Flexibility in spacing shall be provided so that aircraft of varying speed characteristics may be accommodated. The System shall not preclude the use of 500 feet vertical separation. The System shall permit a minimum longitudinal separation of 5 minutes. The System shall permit a minimum lateral separation at any one altitude of 4 miles.

b. The System should be capable of allowing aircraft to climb or descend simultaneously with a prescribed vertical separation.

c. It is preferable that separation of traffic at points of intersection of airways be achieved by vertical spacing whenever possible.

d. Lateral separation shall be used, whenever possible, for changes in altitude.

e. Holding is primarily to be accomplished in Terminal Areas and should not be planned on any airway. If, in spite of this, delaying or holding on an airway becomes necessary, every effort shall be made to divert such held or'delayed aircraft to permit any following aircraft, that could otherwise do so, to proceed.

f. In providing lateral separation of aircraft lanes in the airway areas, adequate provision is required for aircraft in holding or other maneuvers; this is particularly applicable to high speed aircraft. The Svstem shall not require any aircraft to bank in excess of 30°. Sufficient lateral separation to permit holding or maneuvering of high speed aircraft may be obtained by the lateral spacing of the lanes, by granting occupancy of two or more adjacent lanes to such aircraft, or by placing high speed aircraft in one of !he outer lanes of multiple lane airways. For best utilization of airspace with multiple lane airways, the second and third methods appear preferable.

g. At present, not more than two airway lanes are possible for any one altitude on any one airway. In the future, depending on traffic densities, either multiple two lane airways or airways consisting of more than two lanes at any one altitude may be required.

h. The airways shall be such as to occupy as little lateral space as is practicable.

i. Airways should be such that they present the minimum impediment to crossing traffic.

j The number of lanes established on each airway shall be held to a minimum consistent with the volume of anticipated traffic for the airway, with reasonable tolerance allowing for flexibility in aircraft lane assignment and emergency operation.

k. Adequate provision shall be made for aircraft to detour localized weather conditions, such as thunderstorms.

l. The highest limit of Airway Areas shall not exceed 20,000 feet above sea level.

m. The Traffic Control System shall be designed so that Type B Control** may be exercised effectively down to 1000 feet above the terrain.

n. The System should be capable of providing Type B Control, as may be required, in prescribed Off-Airway Areas In other Off-Airway Areas, Type A Control' shall apply.

o. The System shall be capable of allowing aircraft from Off-Airways to enter airways or vice versa.

* Type A Control: Control in the air by regulations and rules but without the aid of a ground facility.

** Type B Control: Control in the air by air-ground coordination or cooperative assistance.

p. The System shall be capable of providing control of long distance flights over routes, including great circle routes, at high altitudes.

q. The System shall permit, as necessary, planning and regulation of traffic flow within the Airway Areas to preclude movements above saturation at crossing or convergence points. Such control shall not limit the acceptance rates established by the terminal.

r. The primary adjustments of aircraft movements to regulate the volume of flow over a period of several hours of terminal utilization shall be accomplished prior to arrival in the Terminal Area.

s. The System shall be capable of supplying all necessary information to an enroute control agency in order that traffic flow may be properly planned and adjusted in the Enroute Area.

t. The Air Traffic Confrol equipment for on-airway use must be usable by aircraft in off-airway areas within the coverage of the system.

u. Surveillance, in addition to normal visual means, shall be provided at all times where traffic density warrants. Surveillance shall operate satisfactorily under all weather conditions.

v. Monitoring of the system is necessary where traffic density warrants.

B. OPERATIONAL PROCEDURES PREDICATED UPON THE AIR TRAFFIC CONTROL PRISCIPLES DEVELOPED

The operational procedures, in order to assure the safe and expeditious movement of air traffic, should be predicated upon the primary concept that all flight movements be governed by the acceptance rate in the Final Approach Area of the terminal airport. Simply stated, the Right to Land* at some terminal must be available to an aircraft before takeoff. The Right to Land does not designate, in any way, the route to be flown. An aircraft only having the Right to Land at some airport near its desired destination may request of the desired destination a terminal acceptance which may be allowed enroute when and if conditions permit.

A Committee with sufficient authority should be appointed to establish policies relating to air traffic scheduling in order that schedules may be prepared by the operating agency and published periodically. These schedules would include detailed information concerning operations of aircraft into specified airports.

* Right to Land: Approved terminal acceptance when required, or a destination not requiring terminal acceptance, give aircraft a Right to Land.

ITEMS	DEVELOPMENT OF PRODUCTION PROTOTYPES						OPERATIONAL APPLICATION					DEVELOPMENT AND APPLICATION TOTALS		
	Prep. of Final Dev. Spec. and Let. of Contract	Dev. & Mfg. of Models for Operation Trials		Operational Trials		Prep. of Prod. Spec. & Letting of Contracts	Mfg. of Production Type Equipment		Installation & Check of Operations		Effective Use Established (a/c suitably equipped)	*Quantity Assumed	Totals	
	Time (Yrs)	Time (Yrs)	Cost (Millions of $)	Time (Yrs)	Cost (Millions of $)	Time (Yrs)	Time (Yrs)	Cost (Millions of $)	Time (Yrs)	Cost (Millions of $)	Time (Yrs)		Time (Yrs)	Cost (Millions of $)
A. Airborne Equipment														
1. Traffic Control (limited channels)														
(a) Transponder (includes simplified Private Line and Display)	3/4	1	$1.0	1/2	$0.3	1/2	1	$15.0	1/2	$5.0	1/2	20,000	4-3/4	$21.3
2. Navigation Equipment (Multichannel)														
(a) Lightweight VHF Nav., & Comm., & Instrumentation	3/4	3/4	$0.4	1/4	$0.2	1/2	1	$ 4.5	1/2	$1.0	1/2	15,000	4-1/4	$ 6.1
(b) Distance Measuring Equipment & Instrumentation	---	---	---	3/4	$0.4	1/2	1-1/2	$60.0	1/2	$10.0	1/2	20,000	3-3/4	$70.4
(c) Arbitrary Course Computer and Instrumentation	---	---	---	3/4	$0.3	1/2	1-1/2	$10.0	1/2	$ 2.0	1/2	20,000	3-3/4	$12.3
(d) VHF Comm. & Nav. Receiver and Instrumentation	---	---	---	1/4	$0.2	1/2	1-1/2	$40.0	1/2	$ 8.0	1/2	20,000	3-1/4	$48.2
(e) Glide Path Receiver (20 channels)	1/2	3/4	$0.4	1/4	$0.2	1/2	1-1/2	$10.0	1/2	$ 2.0	1/2	20,000	4-1/2	$12.6
(f) VHF or UHF Transmitter	---	---	---	---	---	1/2	1-1/2	$20.0	1/2	$ 4.0	1/2	20,000	3	$24.0
														$194.
B. Ground Equipment														
1. Secondary Radar apart from or added to Primary Radar (includes display)	3/4	1	$0.5	1/2	$0.2	1/2	1	$18.2	1/2	$ 4.5	1/2	220	4-3/4	$23.4
2. Distance Measuring Equipment	---	---	---	3/4	$0.4	1/2	1-1/2	$22.0	1/2	$ 4.5	1/2	1,100	3-3/4	$26.9
3. Primary Surveillance Radar (includes display)	---	---	---	1/2	$0.2	1/2	1-1/2	$29.3	1/2	$ 5.0	1/2	220	3-1/2	$34.5
4. Mechanical Interlocks (with Manual Feed)	---	---	---	---	---	---	1	$ 2.0	1/2	$ 0.5	1/2	50	2	$ 2.5
5. VHF Omni Type Range (VOR) Equipment	---	---	---	---	---	1/4	1-1/2	$15.0	1/2	$ 4.0	1/2	300	2-3/4	$19.0
6. VHF ILS Equipment (Include LF Locator Beacons)	---	---	---	---	---	1/4	1-1/2	$18.0	1/2	$ 4.0	1/2	225	2-3/4	$22.0
7. Precision Beam Radar Equipment (includes display) GCA	---	---	---	---	---	1/4	1-1/2	$38.0	1/2	$ 6.0	1/2	225	2-3/4	$44.0
8. VHF-ADF Equipment (includes display)	---	---	---	1/2	$0.2	1/2	1-1/2	$ 2.5	1/2	$ 0.5	1/2	220	3-1/2	$ 3.2
9. Airport Time Utilization Equipment (Simplified)	1/2	1/2	$0.4	1/2	$0.4	1/2	1	$ 1.5	1/4	$ 1.0	1/4	50	3-1/2	$ 3.3
10. Approach Control Timing Equipment	---	---	---	---	---	---	1	$ 1.0	1/2	$ 0.5	1/2	50	2	$ 1.5
														$180.
													Sum Total	$375.

*This chart is an illustration of the means used in estimating the possible total cost of the program. The cost figures and quantities assumed are subject to review by the steering committee recommended in paragraph D3 of Section III of this report.

FIGURE 3A

ITEMS	Study Period	Spec. and Contracts	of Models for Trials		ment Trials		Spec. and Contracts	of Models for Trials		Trials		Spec. and Contracts	Equipment		Operational Check		A/C Equipped	TOTALS	
	Time (Yrs)	Time (Yrs)	Time (Yrs)	Cost *	Time (Yrs)	Cost *	Time (Yrs)	Time (Yrs)	Cost *	Time (Yrs)	Cost *	Time (Yrs)	Time (Yrs)	Cost *	Time (Yrs)	Cost *	Time (Yrs)	Time (Yrs)	Cost *
A. Airborne Equipment																			
1. Traffic Control Equipment (limited channels) Transponder Private Line (including display)	1/2	1	1-1/2	$4.3	3/4	$0.6	3/4	1	$3.6	3/4	$0.9	3/4	2	$68.0	1	$12.0	1	11	$89.4
2. Navigation Equipment (Multi-Channel) (includes instrumentation)	1-1/2	1	2	$1.5	3/4	$0.3	3/4	1	$1.5	3/4	$0.3	3/4	2	$80.0	1	$ 9.0	1-1/2	13	$92.6
																			$182.0
B. Ground Equipment (does not include displays)																			
1. Traffic Data Relay Equipment																			
a. Secondary Radar (Position Determining Eqpt.)	1/2	1	2	$2.0	1/2	$0.2	3/4	1	$2.0	3/4	$0.3	3/4	2	$17.5	1	$ 6.0	1	11-1/4	$28.0
b. Private Line Eqpt.	1/2	1	2	$2.0	1/2	$0.2	3/4	1	$2.0	3/4	$0.3	3/4	2	$33.0	1	$ 4.0	1	11-1/4	$41.5
2. Airport Time Utilization Equipment	1/2	1	1	$0.5	1/2	$0.1	3/4	1	$0.5	3/4	$0.1	3/4	1-1/2	$ 2.5	1	$ 0.5	1	9-3/4	$ 4.2
3. Airspace Separation Equipment (includes tracking circuits)	1/2	1	2-1/2	$4.0	1	$0.4	3/4	1-1/2	$3.0	3/4	$0.3	3/4	2	$15.0	1	$ 5.0	1-1/2	13-1/4	$27.7
4. Flight Path Planning & Flow Control Equipment	1/2	1	3	$4.0	1	$0.4	3/4	1-1/2	$3.0	3/4	$0.3	3/4	2	$40.0	1	$ 4.5	1	13-1/4	$52.2
5. Primary Surveillance Radar (includes ground derived altitude)	1/2	1	3	$5.0	1	$0.4	3/4	1-1/2	$5.0	3/4	$0.4	3/4	2	$100.0	1	$20.0	1	13-1/4	$130.8
6. Nav.Aid Equipment (includes Markers)	1-1/2	1	2	$2.0	3/4	$0.3	3/4	1	$1.0	3/4	$0.3	3/4	2	$50.0	1	$ 5.0	1-1/2	13	$58.6
7. Landing Navigation Eqpt. (includes Markers-handles takeoffs)	1-1/2	1	2	$1.5	3/4	$0.3	3/4	1	$1.0	3/4	$0.3	3/4	2	$45.0	1	$ 5.0	1-1/2	13	$53.1
8. Landing Monitoring Equipment (includes takeoffs)	---	---	---	---	---	---	3/4	1-1/2	$1.5	3/4	$0.3	3/4	2	$40.0	1	$ 5.0	1	7-3/4	$46.8
9. Airport Surface Navigation Eqpt.	1-1/2	1	2	$2.0	3/4	$0.3	3/4	1	$1.0	3/4	$0.3	3/4	2	$15.0	1	$ 4.0	1-1/2	13	$22.6
10. Airport Surface Movement Equipment	---	---	---	---	3/4	$0.3	1	1-1/2	$1.5	3/4	$0.3	3/4	2	$15.0	1	$ 3.0	1	8-3/4	$20.1
C. Ground Displays																			
1. General Planning Display (Symbolic)	1/2	1	1	$0.2	1/2	$0.1	3/4	1	$0.2	3/4	$0.1	3/4	1-1/2	$ 0.5	1	$ 0.3	1	9-3/4	$ 1.4
2. Detailed Flow Display (Pictorial)	1/2	1	3	$0.6	1	$0.1	3/4	1-1/2	$0.4	3/4	$0.1	3/4	2	$ 3.0	1	$ 0.6	1	13-1/4	$ 4.8
3. Detailed Flow Display (Symbolic)	1/2	1	3	$0.8	1	$0.1	3/4	1-1/2	$0.5	3/4	$0.1	3/4	2	$10.0	1	$ 2.0	1	13-1/4	$13.5
4. Displays for Airport Utilization Planning & Control (Pictorial and Symbolic)	1/2	1	3	$0.5	1	$0.1	3/4	1-1/2	$0.3	3/4	$0.1	3/4	2	$ 2.0	1	$ 0.6	1	13-1/4	$ 3.6
D. Point-to-Point Relay Circuits	1/2	1	1	$0.3	1/2	$0.1	3/4	1	$0.5	3/4	$0.1	3/4	2	$24.0	1	$20.0	1	10-1/4	$45.0
E. Air Traffic Control System Simulator	1/2	1	1	$0.3	1/2	$0.1	3/4	1	$0.3	1/2	$0.1	3/4	1	$ 0.8	1/2	$ 0.1	1/2	8	$ 1.7
																			$555.6
																		Sum Total	$737.6

• This chart is an illustration of the means used in estimating the possible total cost of the program. The cost figures assumed are subject to review by the Steering Committee recommended in paragraph D3 of Section III of this report.

*Cost in Millions of Dollars

FIGURE 3B

APPENDIX II

A. OPERATING PROCEDURES

1. General

The greater complexity of the control of air traffic, as compared to that of surface traffic, is due primarily to the following factors:

a. The high speeds of operation.

b. The fact that vertical movement, in addition to horizontal and lateral movement, is involved.

c. The requirement that aircraft operate under zero visibility weather conditions.

d. The inability of aircraft to materially reduce speed, or stop, while in flight when adverse weather or traffic conditions are encountered.

e. The requirement that aircraft of widely varying performance characteristics and opcrational applications be accommodated within the entire airspace.

To improve the efficiency of air traffic flow, the volume of airspace allocated to each aircraft in flight at the present time must be materially reduced. This means that more accurate and more precise all-weather navigation must be provided. Control will require an increase in the rate at which data are gathered, comprehended, and acted upon in the traffic control procedures. It follows that with the anticipated increase in aircraft to be handled on this basis, automatic means of control are necessary as the problem will exceed human capabilities. Attention to simple, clear monitoring of the automatic functions is essential to permit human checking of the operation of such a System.

The establishment of individually distinct lanes over which normal air traffic must flow is essential as a means for permitting human intervention for over-control and for reducing the complexity of equipment design. It is realized, however, that such a discrete track system could lack flexibility if certain precautions are not observed. Flexibility must be retained through implementation which permits rapid choice between a number of discrete track patterns to accommodate changes in weather and changes in the direction of traffic flow. In addition, the System must permit a limited number of special tracks both outside and within the controlled airspace as a means for maintaining flexibility.

The establishment of standard operational procedures and practices, in addition to the discrete tracks, can reduce the variables in traffic control without becoming either an operation.11 "straight jacket" or necessitating excessive training and alertness by air and ground personnel.

2. Such Standards Include:

a. The designation of specific airlane configurations which are standard for all enroute and terminal areas where applicable.

b. The segregation of aircraft into speed categories for purposes of airlane assignment and utilization.

c. The establishment of vertical reference planes across airways as a means for comparing periodically against a fixed datum the locations of all aircraft operating in an associated airspace.

3. Human Judgment Cannot Be Replaced Completely By Automatic Implementation And Must Be Exercised When:

a. Placing aircraft into the System to assure that they are assigned the proper times and positions.

b. Sequencing the flow of traffic as the result of information obtained outside the automatic system.

c. Segregating aircraft into speed categories.

d. Checking the enroute flow to ascertain that flow is as expeditious as practicable.

e. Checking airport acceptances to assure maximum utilization of the airport.

f. Manually controlling emergency traffic.

g. Monitoring it to assure that safe separation is being maintained.

B. GENERAL OPERATIONAL PLAN

1. Division of Control

Control areas are required to establish airspace over which the air traffic control is exercised.

Control areas are divided into two categories:

a. General Control Area which includes portions of the enroute areas and terminal areas except airport control areas.

b. Airport Control Area which includes a prescribed area of limited size for handling arriving and departing aircraft.

2. The General Control Area is Under the Jurisdiction of Two Units.

a. General Planning Unit which handles general flow requirements for the entire General Area.

b. Detail Flow Control Units which handle flight path planning and detailed organization of air traffic. .“a

3. The Airport Control Area is Under the Jurisdiction of an Airport Control Unit.

4. The General Planning Unit Takes Cognizance Of:

a. Acceptance rates of each airport in the area and changes in acceptance rates which may result from weather, runway conditions, and emergencies.

b. Prorating aircraft acceptance times based upon airport schedules.

c. Acceptance of traffic not granted specific landing rights-in the airport schedule (random arrivals).

d. Requests from adjacent General Control Areas for over-flights.

The General Planning Unit will maintain continuous and close liaison with adjacent and other General Control Areas and with its own Detail Flow Control Units.

5. The Detail Flow Control Unit:

a. Sequences, adjusts, and checks detailed traffic flow to assure optimum utilization of airspace and, in turn, optimum utilization of the airports served.

6. Airport Control Unit

This Unit handles aircraft within the Airport Control Area by sequencing and adjusting position of departing and arriving aircraft for the purpose of insuring adequate safe traffic flow. The Airport Control Unit sequences, adjusts, insures adequate safe flow of traffic, and establishes a traffic plan in cooperation with the Detail Flow Control Unit.

Aircraft entering or leaving the airport area will be coordinated with the Detail Flow Control Unit.

C. DETAILED OPERATIONAL PLAN

1. General Planning Unit

Typical operation of the General Planning Unit and implementation requirements associated therewith are as follow-s:

a. Rapid and reliable communication is required between General Planning Units of adjoining areas in order to facilitate the establishment of mutually agreeable rates of aircraft flow per unit of time. These rates of flow are in terms of quantities of aircraft and do not concern specifically named or identified aircraft.

b. The General Planning Unit furnishes acceptance times to origin and intermediate General Control Areas based upon the number of aircraft operating in the area of control and the number of aircraft requesting entrance into the area in the next increment of time.

c. Once the general acceptance rate has been established by route, specific information on each aircraft will be transmitted by the General Planning Unit of the Departure Area to the General Planning Unit of the Arrival Area or to one or more General Control Areas enroute as determined by operational necessity. The specific information trnnsmittcd will include aircraft identification, destination, and estimated arrival time, either to a General Control Area through which the fiight intends to proceed or to the Generail Control Area of destination, whichever is most operationally appropriate.

Within any one General Control Area, the General Planning Unit will transmit spccific information regarding each aircraft to the Detail Flow Control Unit.

2. Detail Flow Control Unit and Airport Control Unit

a. On the receipt of specific information regarding each aircraft, the Detail Flow Control Unit will coordinate with the Airport Control Unit involved and establish the proposed plan of operation at the Vertical Reference Plane at the enroute-terminal boundary. This information will include aircraft identification, destination, lane, and time aircraft should use airspace with respect to this Reference Plane.

b. The Airport Control Unit will make final adjustments to sequence aircraft by lane and time with respect to the airport Vertical Reference Plane.

c. To insure that the proposed plan of operation with regard to the Vertical Reference Plane serving the enroute-terminal boundary can be made good for both inbound and outbound traffic, it may be essential that similar data with respect to one or more Vertical Reference Planes out along the route be utilized. Utilization of the data will be automatic.

d. The Detail Flow Control Unit for the various routes will receive progress information with respect to Vertical Reference Planes. This information will be received by the Detail Flow Control Units periodically or continuously. The Detail Flow Control Unit can reserve airspace by the establishment of plans with respect to Vertical Reference Planes.

e. If the aircraft progress is within specified tolerances, the System will indicate to the aircraft that its progress IS satisfactory.

Aircraft in the System will have their positions compared against the planned data in the System.

f. If the aircraft progress is not satisfactory and does not meet the proposed plan with respect to the Vertical Reference Plane involved, appropriate automatic signals will be sent to the aircraft concerned.

Reassignment of aircraft to new airlanes and/or new times while enroute is accomplished by referring to the originally proposed flight plan and the actual progress made good. The Detail Flow Control Unit knows the status of airspace and airlane availability and can accommodate additional aircraft or reassign existing aircraft to maintain optimum flow.

g. At the time of insertion of additional aircraft in the System, the pertinent information is transmi!tcd to other Detail Flow Control Units to assure the expeditious movement of :hc new aircraft.

h. Means will be available for both Detail Flow Contro! Units and Airport Control Units to establish lanes between enroute Reference Planes and airport Reference Planes.

3. Long Distance High Altitude Operations

The Air Traffic Control System will provide for aircraft operating at altitudes above 20,000 feet. It is probable that aircraft operating above 20,000 feet will not follow flight paths which coincide with routes established for operation below 20,000 feet. Provision will be made to handle the high altitude operation on an area basis using individual Reference Planes as may be required.

To avoid interference between high level and low level operations, separate climb and descent lanes will be provided wherever possible.

4. High Speed Operation

The Air Traffic Control System will, on an area basis, establish special lanes for very high speed aircraft.

5. Random Crossing Flights

The Air Traffic Control System will provide crossing lanes at any desired location by reserving adequate airspace at the proper time intervals for the crossing aircraft.

D. CHART I EXPLANATION

DETAIL OPERATIONAL PLAN A. T. C.

This chart shows three airports and four routes servinga terminal area. ‘it shows Reference Planes associated with each route and a second set of Reference Planes associated with each airport. The chart is diagrammatic and does not represent geographic relationships.

This situation was selected to explain the new operations concept of the integrated Air Traffic Control System. In this new concept, Reference Planes at fixed geographic locations are used as basic datum for correlating aircraft movement.

In order to follow the flight of each aircraft, refer to numbers assigned to the aircraft. The corresponding numbers show the subsequent position of the aircraft in its flight path.

1. Reference Plane Al

a. Local Inputs to Equipment which Operate with Respect to Al

(1) Identification (destination), track, direction, altitude, and time (List H - from explanation of Chart II - Items 1 to 5) from each aircraft.

Time, direction, track, and altitude are derived for each aircraft in terms of relation to Reference Plane Al.

(2) The geographical location of Reference Plane A1 is a factor built into the equipment for Al and can be changed by adjustment.

(3) The local inputs are transmitted continuously.

b. Remote Inputs for Al from Detail Flow Control Unit of - P -

The desired traffic arrangement, including sequence by time and lane and destination for each aircraft.

This desired arrangement is the result of correlation of the large volume of data in the Detail Flow Control Unit (List C from explanation of Chart II). The desired plan is set up by the Detail Flow Control Unit in terms relating to the constant Reference Plane .A1 and is transmitted to the equipment **for Al as:** ldentificatiun (destination), lane, and estimated arrival time at Reference Plane Al.

c. Storage of Data for Al

The desired traffic plan (shown above as a remote input) is stored for later comparison with local inputs at the appropriate time. The local inputs are transmitted to the equipment **for** Al continuously as indicated above. The remote inputs, the dcsircd traffic arrangement planned in advance, is transmitted periodically and is revised as required to accommodate changes in sequence or the addition of new traffic.

d. Operational Outputs of Al

(1) Using Reference Plane at Al, the equipment compares the actual positions of aircraft **(by** time and lane) with the desired positions planned in advance and transmitted from Detail Flow Control Unit.

(2) If the comparison of actual position (by time and lane) with the desired plan finds the flight within the allowable tolerance, for example -- f 3 minutes, the flight is allowed to **proceed.** The equipment for Al acts automatically to direct the flight (up, down, right, left, hold, or proceed) in order to: (a) change flight from actual lane to desired lane, (b) create the proper sequence of flights on a particular lane to Reference Plane A1, and (c) establish average rate of flow past A1 at the level specified by Detail Flow Control Unit. Detail Flow Control Unit varies the flow past this Reference Plane in order to adjust further the flow of traffic to the receiving airports.

NOTE: (a), (b), and (c) above will arrange the traffic in accordance with the plan set up in advance by Detail Flow Control Unit. After flights are accepted and started through the sequencing functions of (2) (a), (b), and (cl, the time positions **of** flights with respect to Al may vary from these time positions planned in advance. This variation will arise as the output rate of flow past Al is varied front the input rate of flow planned in advance. Such variation will normally be in the same proportion for all flights. Detail Flow Control Unit will be apprised periodically of such variation and may, by taking no action, allow the originally planned sequence (by time and lane) to remain unchanged. As the variation between this advance plan and actual flow past Reference Plane Al makes it necessary, Detail Flow Control Unit will advise the General Planning Unit to make corresponding adjustment in the overall flow of traffic from points of origin.

(3) If the comparison of actual position (by time and lane) with the desired plan finds the flight outside the allowable tolerance, the equipment will: (a) insofar as possible act automatically to put the flight back in step with the plan set up for A1 by Detail F low Control Unit. The equipment does this by telling the flight to go up, down, right, left, **speed** up, slow down, hold, or proceed; (b) the equipment for Al calls Detail Flow Con**trol** Unit's attention to the flight in question together with sufficient situation data to permit Detail Flow Control Unit to revise the plan set up at Al if that **is** required. When the plan has been revised or allowed to remain as is, the automatic equipment **allows** the flight to proceed and sequences the flight in accordance with (2) (a), (b), and (c) above.

(4) In order to arrange and sequence the traffic as outlined in (2) (a), (b), and (c), the plan set up for Al will be extended to A2 and to other Reference Planes along the route, as required. This is recognition of the fact that (2) (a), (b), and (c) will have to be accomplished in relation to more than one Reference Plane. It is anticipated that the number of Reference Planes required to accomplish the functions of (2) (a), (b), and (c) will be **in** proportion to the anticipated density and speed **of** traffic.

(5) Situation data with respect to Al, A2, and other Reference Planes along the route and **for** specific portions of the routes beyond the Reference Planes A1, A2, etc., will be available to Detail Flow Control Unit. Control of these airspaces will be available to Detail Flow Control Unit to: (a) rearrange traffic, (b) reserve airspace for uncquipped aircraft, (c) reserve airspaces for random flight tracks through the controlled area, **and** (d) insert additional traffic at any point along the route.

The above data, when requested by Detail Flow Control Unit, include: Identification (destination), estimated arrival time at Al, and actual position of each flight for which display is required in terms of lane and distance from fixed reference.

2. Reference Plane In

The use of Reference Plane In and the iunctions oi associated equipment for Ia arc essentially the same as the use and functions of equipment for Al except that:

a. Two control units (the Detail Flow Control Unit and the Airport Control Unit) coordinate to set up the advance plan for Ia. This coordination takes place as follows:

(1) Airport Control Unit tells Detail Flow Control Unit it can accommodate so many aircraft on specific lanes.

(2) Detail Flow Control Unit coordinates information (1) with respect to Ia, IIa, etc., to establish advance plans with respect to Al, Bl, etc.

(3) Detail Flow Control Unit gives Airport Control Unit the advance plan with respect to Ia. This plan consists of those parts of advance plans with respect to Al, Bl, etc. as are appropriate to Ia.

(4) The flow control equipment compares the actual time positions of aircraft approaching Ia from Al, Bl, etc., with the advance plan set up with respect to Ia.

(5) **If** the position of a flight entering the area adjoining Reference Plane Ia is found to be within an allowable tolerance of the advance plan, flight is allowed to proceed, and no indication to or action by Airport Control Unit should be required. (The tolerance allowed here may be less than that allowed entering the area adjoining Reference Plane Al but will be greater than the tolerance required of traffic leaving Reference Plane Ia to the runway).

(6) If the position of a flight entering the area adjoining Reference Plane Ia is found to differ from the advance plan with respect to Ia by more than the allowable tolerance, the equipment calls the attention of the Airport Control Unit to this fact. The Airport Control Unit revises the advance plan for In if this is required.

b. It is the Airport Control Unit which adjusts the flow of traffic past Reference Plane Ia in order to make best use of the runway under the conditions existing at the moment. Since this traffic flow from Ia to the runway may occasionally be greater or less than the planned flow entering the area adjoining Ia, the actual time positions of a11 flights would be proportionally ahead or behind the advance plan. The Airport Control Unit would be periodically apprised of this variation as required. This Unit will normally allow the sequencing (as described in 1.d (2) (a), (b). and (c)) to continue without revision of the advance plan. If and when required, the Airport Control Unit will request the Detail Flow Control Unit to readjust the f!ow past Al, Bl. etc., in order to keep the variation between actual flow and planned flow at Ia within prescribed limits.

c. There is greater need for continuous and accurate position and time reporting in the area between Al and Is than was the case prior to passing AI.

d. It is also recognized that the extreme time accuracy required of flights passing Ia enroutc to the runway may require a special function to be performed at Ia that was not needed at Al; in other words, the final exact time adjustment of flights to achieve maximum utilization of the runway.

3. Links

a. Area PI. General Planning Unit. Area PI receives information from General Areas P2 and P3 concerning number of aircraft per unit **of** time desiring to fly over routes C and A to airports I and II (through Link 51.

(1) PI correlates information and authorizes proportion of number of aircraft that can be accommodated by airports of Gencral Area PI.

(2) P2 and P3 will send aircraft IDENT. destination, and estimated arrival time to PI.

b. Area Pl. General Planning Unit tells Detail Flow Control Unit: (1) number of aircraft authorized by unit of time for eah route to each airport; (2) aircraft IDENT, destination, and estimated arrival time (through Link 6).

(1) Detail Flow Control Unit coordinates with the Airport Control Unit of I and establishes acceptance positions at Ia (through Link 1 from I).

(2) Detail Flow Control Unit establishes reservation of airspace by time, lane, IDENT, and destination at Al (through Link 2).

(3) Detail Flow Control Unit is advised, either continuously or at specified time intervals, of progress of specific aircraft by lane with respect to Reference Plane Al (through Link 2).

(4) Detail Flow Control Unit has the record of the proposed plan for comparison of progress of actual operation. After aircraft pass Al, this aircraft's record is removed from Detail Flow Control Unit.

(5) General Planning Unit is provided with information of actual progress of aircraft (through Link 4).

(6) Detail Flow Control Unit establishes automatically the extension of proposed plan set up for Al to reference planes A2 and A3 through link 3 (through Link 2).

(7) Information on progress of aircraft between Reference Planes, such as Al-A2 and A-2-A3, is transmitted through Link 3.

c. Detail Flow Control Units. They receive through links 2 and 3 information on aircraft by unit of time in order that flow adjustments can be made.

(1) Air traffic is sorted and sequenced at Al to carry out the detail control clearances received on link 2 from Detail Flow Control Unit. This operation consists of:

(a) Sorting traffic by destination.
(b) Sequencing traffic by time.
(c) Limiting the flow to the total established for each airport.
(d) Feeding traffic into the proper lanes by destination.

(2) Detail Flow Control Unit is told how far (in time) aircraft are ahead or behind that planned in advance for Al. This will indicate amount of backlog being built up, if any, at Al. If the information indicates a change in overall flow requirements. this information will be provided General Planning Unit for appropriate action (through Link 2).

(3) Detail Flow Control Unit is told how much the actual landing operation is ahead or behind, the flow planned previously to pass Ia. If any adjustment is required, Detail Flow Control Unit will adjust through link 2 as aircraft pass Al (through Link 1).

(4) Coordination of use of airspace is handled by proposed plans for passing Reference Planes and is extended tc the two Reference Planes at the boundary between General Control Areas. If there is any conflict, Detail Flow Control. Units oi both General Control Areas are informed, and corrective action is taken (through Link 3)

E. CHART II EXPLANATION

PLAN FOR TRANSMISSION OF INTELLIGENCE (Air Traffic Control)

This chart shows the flow of intelligence between terminal and enroute areas and aircraft necessary to control traffic. The chart shows two towers, two centers, and four enroute facilities. Also shown are the connecting communications links between operations office, ATC centers, control towers, communications stations, and aircraft.

The "boxes" shown on this chart indicate what information is required for the display and coordination necessary to move air traffic. The "boxes" indicate what requirements are necessary for establishing proposed air traffic patterns, including issuance of clearances to accomplish adequate separation and flow of air traffic.

The lists indicated in the various "boxes" and contained in the following pages show what information will be transmitted, when appropriate, to other locations. The communications links shown with their arrows indicate where this information will bc sent. In most cases, all the information listed will not be sent at any one time or with regard to any one aircraft.

The density of air traffic and the situations at any specific time will dictate what items of the lists will be transmitted to handle the existing situation. The lists show all items which may be required to handle any situation that may develop in the movement of air traffic in prescribed arcas.

Lists A, C, D, E, F, G, and H that follow refer to the boxes on the chart that are simiiarly lettered. (There is no List B.)

1. List A

Proposed Flight Plan

1. Identity - Type and number of aircraft.
2. Point of departure (position, if airborne).
3. Route of flight.
4. Proposed altitudes.
5. Destination.
6. Speed (air),
7. Status of equipment.
   (a) in aircraft
   (b) operational status.
8. Proposed time of departure.
9. Estimated elapsed time to destination.
10. Pilot's information and request.
11. Alternate airport.
12. Fuel on board expressed in flight time.
13. Pilot's name.

1st Use

Flight plan to indicate proposed operation by a pilot.

2nd Use

Storage for reference purposes, as required. Items 11 and 12 capable of being revised at will during flight.

3rd Use

When received in Air Traffic Control Center minus items 11. 12, and 13, becomes the basis upon which control action is initiated and forms part of List C.

2. Cist

ATC Center Information

I. Identity, type and number of aircraft.
2. Point of departure (position, if airborne).
3. Route of flight.
4. Altitude (proposed by departing aircraft).
5. Destination.
6. Speed (air).
7. **Status of** equipment.
   (a) in aircraft.
   (b) operational status.
8. Proposed time **of** departure.
9. Estimated elapsed time to destination.
10. Pilot's information and request.
11. Status of airspace.

12. Route liaison
    (a) advanced information
    (b) acceptance rate - (destination - predetermined in majority of cases - other on individual basis)
    (c) acceptance rate - (of own center area)
13. Weather information.
14. System monitor (equipment).
15. Surveillance.
16. Controller information.
17. Progress.

1st Use

Items 1 - 10 form basis for initiating control action for a departing flight.

2nd Use

Items 1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 15, 16 and 17 form basis for determining control instructions to a departing aircraft and amended control instructions to aircraft enroute.

3rd Use

All or any part of the list forms basis for determining that information should be passed between controllers or that coordination is required.

4th Use

Items 1, 2, 3. 4, 5, 6, 7, 8, 10, 11, 12a, 12b, 13, 15, 16, and 17 form basis for determining control instructions to be issued as final enroute clearance.

3. List D

ATC Center Action

1. Identification of flight by aircraft number.
2. Departure time is-. (Based on acceptance time at destination.) (Normally 2 is supplied pilot soon after submitting flight plan for pilot planning.)
3. Hold.
4. If hold, where?
5. Proceed -- (Let pilot know he is authorized to proceed to destination requested - A clearance limit (intermediate point) may temporarily be imposed.)
6. Assignment of position
    (a) Time (or distance to go).
    (b) Altitude.
    (c) Heading of plane (direction).
    (d) Track.
7. Position with respect to other aircraft.
8. **Verification** of information transmitted (includes acknowledgment).
9. Weather.
10. Estimated acceptance time (also significant changes).
11. Controller to controller information as necessary.

1st Use

Departure time instructions.
Items 1 and 2.

2nd Use

Initial Enroute Clearance.
All or any part of the items, as appropriate.

3rd Use
Enroute Clearance Amendment.
All or any part of the items, as appropriate and as required.

4th Use
Transmission of Control Information Between Controllers.
All or any part of the items, as appropriate and as required. (In form of information or request on coordination basis.)

5th Use

Final Enroute Clearance.
All or any part of the items as appropriate and as required to meet flow plan for destination.

4. List E

Pilot Action - On Airport

1. Identification - type and number of aircraft.
2. Position of aircraft on field.
3. Time aircraft is ready to:
   (a) Leave gate (or present position).
   (b) Take live runway.
4. Destination on airport.
5. Progress.
6. Verification of action requested.

1st Use

Request for Taxi Clearance
Items 1, 2. 3a, 4, and 6. (Items I - 6 for amendment of taxi clearance.)

2nd Use

Indication of Progress.
items 1 - 6.

3rd Use

Request for Clearance to Take Live Runway.
Items 1, 2. 3b, and 6.

5. List F

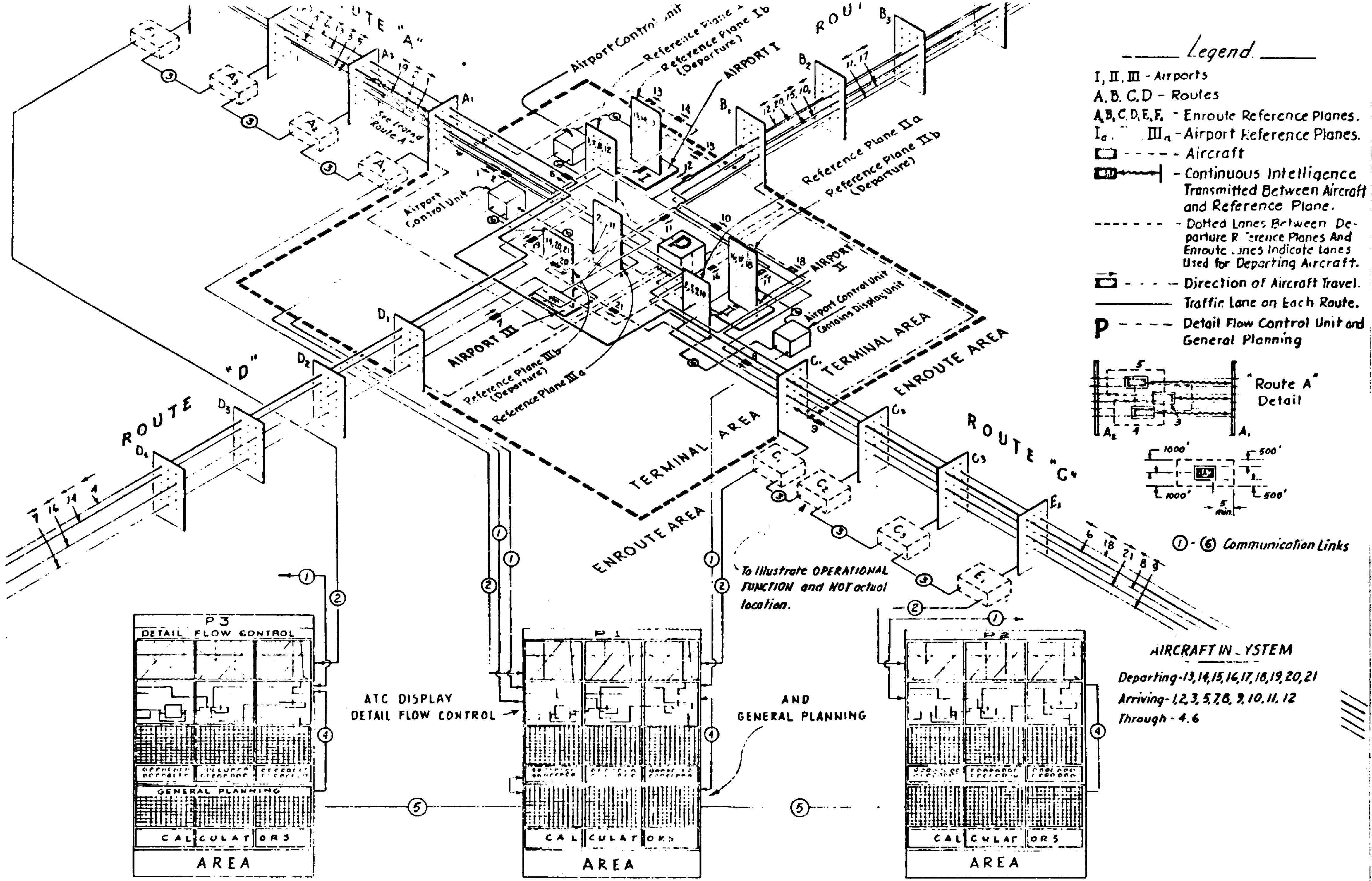
Tower Information

1. Identification - type and number of aircraft.
2. Destination airport.
3. Direction of motion on airport.
4. Taxi lane.
5. Position of aircraft.
6. Controller's information.
   (a) What instructions have I issued?
   (b) What instructions has the ATC controller issued?
7. Status of airspace and taxi area (information on all other aircraft includes 6 and 9 on aircraft which may conflict!.
6. Time when departing plane will be ready to:
   (a) Leave gate (or present position)
   (b) Take live runway.
9. Time when arriving plane will be ready to:
   (a) Enter initial approach area.
   (b) Final approach.
   (Note: 9a and 9b are derived from 5)

Departing Aircraft

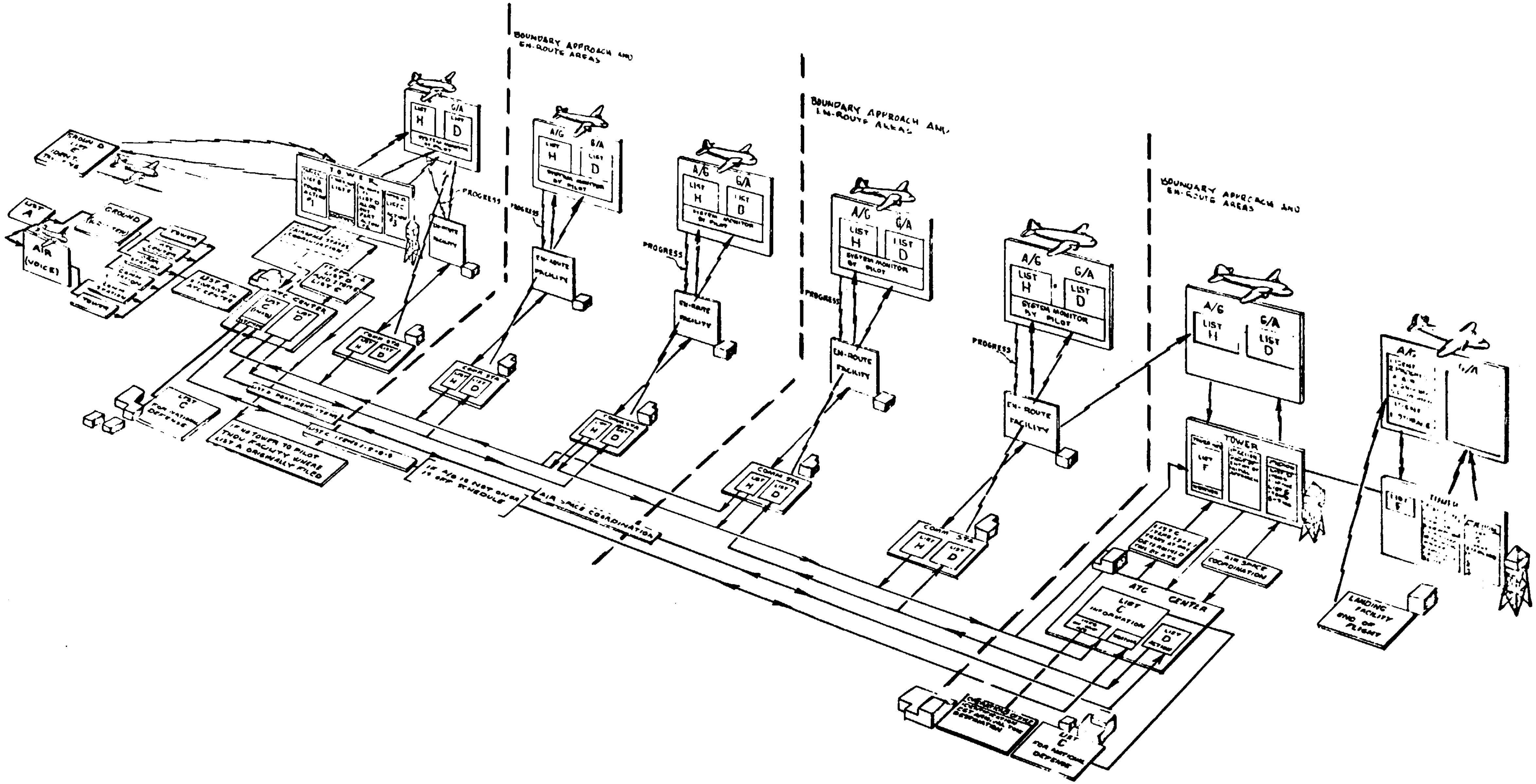
1st Use

Items 1, 2, 3, 4, 5, 6a, 6b (when required), 7, and 8a form basis for determination of initial



DETAIL OPERATIONAL PLAN A.T.C.

CHART I



PLAN FOR TRANSMISSION OF INTELLIGENCE
(AIR TRAFFIC CONTROL)

CHART II

taxi instructions. (Items 1, 2, and 5 form basis for requesting enroute clearance when required).

2nd Use

Items 1, 5, 6a, 6b, 7, and 8b form basis **for** detertnination of instructions to take live runway and departure instructions.

3rd Use

Items 1, 2, 5, 6a, 6b (when required), and 7 form basis **for** determination of control instructions for airborne aircraft in the airport area.

4th Use

Items 1, 2, 3, 4, 5, '7, 8a, and 8b form basis for transmission of control information to ATC Center (in form of information or request).

Arriving Aircraft

1st Use

Items 1, 2, 5, 6a, 6b, 7, 9a, and 9b form basis for determination of control instructions from airport reference plane to final approach and amended instructions.

2nd Use

Items 1, 5, 6a, 7, 9a, and 9b form basis for determination of control instructions from final **approach to the airport.**

3rd Use

Items 1, 3, 4, 5, 6a, 7, and 9b form basis **for** determination of taxi instructions and amended instructions.

4th Use

Same as 3rd use under departing aircraft but in the initial and final approach areas.

5th Use

Same as 4th use under departing aircraft.

Note: 3rd use under departing aircraft and 4th use under arriving aircraft are integrated as one function when arriving and departing aircraft are in the area.

6. List G

Tower Action

1. Identification - type and number of aircraft.
2. Departure time is-. (Based on **local** conditions as well as acceptance time at **destination.)**
3. Time check.
4. Altimeter setting.
5. **Wind and velocity.**
6. **Runway in** use.
7. Airport situation.
8. Taxi lane.
9. Where hold.
10. Position.
11. Proceed.
    - **(a)** Cautioq.
    - **(b)** Unrestricted.
12. Direction of motion,
    - **(a)** Right - Left.
    - **(b)** Right - Left - Up - Down.

13. Time to take action.
14. Position with respect to other aircraft.
15. Verification of pilot's action. (Acknowledge)

1st Use

Taxi Clearance
All or any part, as appropriate, for issuing initial taxi clearance and amended taxi instructions.

2nd Use

Clearance to enter live runway
Items 1, 11a or 11b, 13, 14, and 15 (when required, Items 5, 7, 9, 10, and 12a).

3rd Use

Departure Clearance
Items 1, 11a or 11b, 12a, 13, 14, and 15.

4th Use

Clearance from Enroute Reference Plane to Initial Approach Area
Items 1, 4, 10, 11a or 11b, 13, 14, and 15 (when required, 9 and 12b).

5th Use

Clearance to enter Final Approach
Items 1, 3, 5, 6, 7, 10, 11a or 11b, 13, 14, and 15 (when required, 9 and 12b).

7. <u>List H</u>

Pilot Action - Airborne

1. Identification - type and number of aircraft (may include destination).
2. Track.
3. Direction.
4. Altitude.
5. Time.
6. Position.
7. Hold (I AM).
8. Proceeding.
9. Up-down-right-left (I AM).
10. Distance to go (tied in with 5, 6, and 8).
11. Weather.
12. Pilot's request.
13. Significant change of speed.
14. Acknowledgment of pilot action,
15. Pilot's acknowledgment.

1st Use

Navigational information to pilot
Items 1, 2, 3, 4, 5, 6, 10, 13, and 15.

2nd Use

Progress and traffic control information to ATC and/or tower
Items 1, 2, 3, 4, 5, 6, 10, 11, 13, and 14 (when required, 7, 8, and 9 as appropriate to situation).

3rd Use

General information to ATC and/or tower
Items 1, 6, 14, and 11 or 12, as appropriate.

APPENDIX III

DETAILED EQUIPhIENT_CHARACTERISTIC~

A. TRAFFIC CONTROL EQUIPlMENT (Airborne - Equipment No. I)

REQUIREMENTS FOR THE ULTIMATE SYSTEM

1. Objective

The purpose of the airborne traffic control equipment is:

a. To provide a transponder which will reply to ground interrogator equipment used for traffic control.

b. To provide facilities for air-ground private line (addressed) communication.

2. Functional Characteristics

a. The functional characteristics of the airborne traffic control equipment shall be:

(1) To permit the interrogator to determine three-dimensional position information (R, Θ, H).

(2) To permit the interrogator to determine the responding aircraft's identity.

(3) The inherent delay of all airborne transponders in replying to interrogations shall be standardized and remain constant under service conditions lo within $\pm$ 0.2 microsecond as dictated by approach zone accuracy requirements. In the enroute zone, where greater variations in signal amplitudes exist, the delay may be permitted to increase to $\pm$ 1.0 microsecond.

(4) To provide for the automatic, fail-safe, transmission of Air Traffic Control information (clearances, requests, confirmations, etc.) between aircraft and the control agency. This shall include the ability to transmit air-derived navigational information to the control agency.

(5) To provide for the automatic, fail-safe, transmission of Air Traffic Control information, clearances, and confirmations between the control agency and aircraft.

(6) To make possible the display of the intelligence transmitted over the private line using indicator signals and simple displays.

(7) To make it possible to communicate with an aircraft on the basis of its occupancy of a "block" of airspace without knowledge of the aircraft's identity and without requiring cooperation of the aircraft's navigational equipment. The dimensions of the airspace "blocks" are approximately five miles square with a vertical thickness of 1000 feet.

3. Use

The transponder and private line equipment shall be carried by all aircraft and shall be usable for all airspace.

4. Relation to Other Equipment

a. The positional information derived from the air traffic control equipment (both in thc enroute and in the terminal areas) will be utilized by the control equipment on the ground to determine occupancy of airspace and the identity of the occupant.

b. The airborne private line equipment will transmit air to ground:

(1) Pilot requests.

(2) Confirmation of signals received from the ground to insure fail-safe operation.

(3) Position data (R, Θ) from the instrument circuits of the navigation equipment.

(4) Altitude from a barometric altimeter or an aneroid capsule.

5. Weight and Volume

a. The airborne air traffic control equipment proper shall not weigh more than 20 lbs.

b. The combined equipment exclusive of antenna, cabling, display, etc., shall not occupy more than the volume of a conventional JAN AI-D unit, and the display unit shall be capable of mounting on an instrument panel in an area not greater than 16 square inches.

REQUIREMENTS FOR THE INTERIM SYSTEM - TRANSPONDER

No equipment has been designed which satisfies the requirements set forth above. Study has been instituted to determine the line of development of the airborne transponder. This study will include an analysis to determine whether the transponder can be reasonably combined with the private line in one equipment.

1. Objective

The objective is to provide airborne equipment capable of furnishing coded replies to assist radar interrogators in the determination of bearing and distance (R/Θ) of the aircraft. It shall also be capable of furnishing altitude continuously and identity upon request.

2. Functional Characteristics

The functional characteristics of the interim transponder shall be:

a. To answer all interrogators used for traffic control when within the distance range of their cover.

b. To aid the interrogator in the determination of plan position information (R, Θ) and altitude information.

c. To make it possible for the interrogator to determine the responding aircraft's identity.

3. Relation to Other Equipment

See Paragraph A-4.

4. Weight and Volume

The transponder shall weigh no more than 30 lbs. and shall occupy one JAN Al-D unit.

5. Frequency Coverage

See Section III, Part F.

REQUIREMENTS FOR THE INTERIM SYSTEM - PRIVATE LINE

No equipment has been designed which satisfies the requirements set forth above. For the present, communications with aircraft must be handled by interference-free voice transmission. Study has been instituted to develop a private line capable of actuating indicator signals. This study will also establish whether the private line can be reasonably combined with the airborne transponder into one equipment.

1. Objective

The Control Agency must be able to send certain traffic information and clearances to the aircraft at periodic intervals. The aircraft must have the means to request changes in these clearances and to send reports. The reports include navigational information as seen by the pilot.

2. Functional Characteristics

Except for the requirement that the Control Agency be able to communicate with a block of airspace without knowledge of the occupying aircraft's identity and the requirement that the private line and transponder be one equipment, the ultimate requirements apply to the interim equipment. Additional detailed requirements are as follows:

a. Any ground station shall be able to communicate with each aircraft within its cover.

b. Control shall pass from ground station to ground station without requiring any adjustment of the aircraft equipment by the pilot.

c. The time interval between air-derived position reports shall be less than 30 seconds.

d. The time interval between private line transmissions shall not exceed 10 seconds. It is highly desirable that this interval be made as short as economically feasible.

e. No entirely suitable technique is now known for'communicating with a block of airspace from a single site system without knowledge of aircraft identity andjor without relying on the aircraft's navigational instruments. Since it may be necessary to handle many aircraft on a single frequency in the same area, some method of time division. is required. Two methods appear to offer promise:

(1) Time Assignment.

If a six second cycle is chosen and each plane is assigned a 3000 microsecond interval in each such cycle, 2000 aircraft can be handled in an area on the same pair of frequencies (one for air-to-ground and one for ground-to-air). This method would require synchronization of all ground stations and al1 aircraft in the area.

(2) License Number Assignment.

This method is to call each aircraft by license number, using a pulse code. Synchronization is required on the ground to prevent adjacent transmitters from operating simultaneously, but no synchronization of aircraft is required.

Either method is feasible and the choice may well be governed by the complexity of the aIrborne equipment. Active study is in progress to determine the least complex system.

3. Use

The private line equipment shall be installed as rapidly as feasible in all aircraft intending to enter high density traffic areas.

4. Relation to Other Equipment

See Paragraph A-4.

5. Weight and Volume

Estimated 45 lbs. and case size JAN Bl-Dl.

6. Frequency Coverage

See Section III, Part F.

B. NAVIGATIONAL EQUIPMENT (Airborne - Equipment No. 2)

1. Objective

To furnish, within the aircraft, the required information:

a. For navigating in the enroute (on and off airways), initial approach, and holding areas.

b. For approach to landing on and departing from a predefermined runway.

c. For navigating on the airport surface during all weather conditions and during conditions of heavy traffic density.

This airborne equipment also provides the receiving link for a situation display of the air and ground areas in which the aircraft is operating and the transmitting and receiving link for air-ground aural communication.

2. Functional Characteristics

a. In the enroute (on airways and off airways), initial approach, and holding areas, the aircraft equipment shall be used with Ground Nav-Aid Equipment (No. 5).

(1) The equipment shall provide the pilot a continuous visual indication of the distance and bearing from any point which he may select within the coverage of the system and shall provide him with continuous visual indications which will allow him to follow any operationally desirable track with respect to this point.

(a) The Nav-Aid Equipment shal! develop navigational information in polar coordinates.

(b) The instrumentation and/or computer used in the airborne equipment shall permit the establishment of airways having parallel traffic lanes, These traffic lanes shall have a spacing of 5 miles laterally and 1000 feet vertically. In a vertical direction, coverage shall be continuous to at least 20,000 feet, except for the line-of-sight limitations.

(c) The equipment shall supply information for both manual and fully automatic flight.

(d) The system accuracies, including the airborne equipment, are listed in detail in the characteristics oi the Nav-Aid Equipment.

(e) The bearing of the aircraft from the facility ground site shall be determined in the airborne receiver and associated circuits from the ground transmitted signals without requiring the use of an airborne transmitter.

(f) The distance of the, aircraft from the ground facility shall be derived in the airborne equipment using signals of the airborne transmitter for iterrogation of the ground equipment and reception by the airborne receiver of the response.

(g) The airborne equipment shall contain the necessary means for deriving positional Information (R/O) at all points within a radius of 115 statute miles of the facility at all altitudes except as limited by radio wave propagation characteristics.

(h) Adequate warning to the pilot shall be given automatically in case of malfunctioning of either airborne or ground portions of the system.

b. In the final approach and landing aress, this airborne equipment shall be used with the Landing Navigation Equipment and Monitoring Equipment (Equipment No. 6). in general, where applicable, the system requirements listed under these ground facilities shall also apply to this airborne equipment.

(1) The equipment shall provide in the aircraft the necessary instrumentation to enable the aircraft to navigate in the approach area to the touchdown area on the runway and along the runway proper.

(a) The equipment shall provide, in the aircraft, precise, continuous, information on the position of the aircraft relative to the optimum flight path. Heading is a necessary adjunct to this visual indication; however, it may be derived from another source.

(b) The equipment shall provide, in the aircraft precise, continuous, visual indication of the distance of the aircraft from the touchdown point on the runway.

(c) The equipment shall provide, in the aircraft, continuous indication of the position of the aircraft relative to the optimum landing slope.

(d) The equipment shall provide for both automatic and manual flight to a landing.

(e) The airborne transmitters required shall be cpable of interrogating the ground equipment from any point within the areas listed in system requirements.

(f) The system shall provide, in the aircraft, inimediate and positive indication of malfunctioning of any part of the system.

(g) If an adjustable landing slope of limited range is desired, it shall be adjusted within the airborne equipment. The circuits used shall prevent adjustment of the landing slope below that normally used on the airport involved.

(h) In order to use the flare-off of the optimum landing slope, it will be necessary to limit the permissible variation in height of the airborne antenna above the ground when the aircraft is in the landing position at the touchdown point. It may be ncc-essary to provide a separate airborne antenna, from the one used in other operational areas, in order to meet this and other desired performance characteristics.

(i) The system shall be of such a character that the basic airborne components shall be the same as used with the Nav-Aid Equipment (Enroute Area).

c. For purposes of the control and navigation of aircraft on the ground, this airborne equipment shall be used with the Airport Surface Aeronautical Equipment No. 7(b). In general where applicable, the system requirements listed under this ground facility shall also apply to the airborne equipment.

(1) The equipment shall be used to provide navigational information to the aircraft while on the airport surface.

(a) Navigation and group traffic control information shall be presented to the pilot via the situation display.

(b) Aircraft with partially disabled equipment shall obtain traffic control and nnvigs-tion information through other visual means and through aural radiocommunication.

(c) Traffic Control information directed to an individual aircraft will be handled via the private line.

d. Voice communication from ground-to -air and air-to-ground shall be provided, over this equipment, withou: a reduction in the performance of the navigational and situation display functions.

(I) The area of coverage by the communications means shall be the same as the navigational coverage from the facility being used.

e. Means for receiving the situation display information transmitted over the ground navigational facility shall be provided in this equipment. Reception of this information shall be provided without a reduction in the performance of the navigational and aural communication functions.

(1) The area of coverage over which the situation display information can be received, by the airborne equipment, shall be the same as the navigational coverage from the facility being used.

3. Use

The navigational equipment shall be carried by all aircraft.

4. Relation to Other Equipment

This airborne equipment:

a. In cooperation with Nav-Aid Equipment No. 5, provides navigation information in the en-route and in the terminal areas.

b. In cooperation with the Landing Navigation Equipment So.6 (b), provides approach and landing information in the terminal area.

c. In cooperation with the Airport Surface Navigation Equipment No. 7(b). provides navigational information while on the airport surface.

d. Provides situation display and aural communication in cooperation with Equipment No. 5, G(b),and 7(b).

e. Supplies navigational information to Traffic Control Equipment No. 1 for transmission to **the** ground.

5. Weight and Volume

a. The basic airborne equipment shall weigh no more than 20 lbs. and shall occupy one JAN Al-D case.

b. While the basic airborne components **of** the system will render uniform accuracy to all **classes** of aircraft, it is recognized that in certain classes of aircraft it will **be** desirable **to make** installation of additional airborne equipment and instrumentation beyond the minimum requirement in order to improve the convenience **and** flexibility of the operation of the aircraft.

6. Frequency Coverage

See Section III. Part F.

C. AIRBORNE DISPLAY (Pictorial and Symbolic - Equipments No. lb and No. 2b)

1. Objective

To provide pictorial situation display to aircraft of appropriate portions of the traffic data **which** are available on the ground and to provide a symbolic display of information required in air traffic control.

2. Functional Characteristics

a. The Pictorial Display (Equipment No. 2(b)) shall display within the aircraft:

(1) The position of each lane in each altitude layer in the enroute, terminal, and airport areas.

(2) The location of all obstacles to flight in each altitude layer and in the next adjacent **layers, above** and below. Each layer shall include the specific levels of 1000 feet **above** and below the 1000 foot level on which the aircraft is operating.

(3) The location of each aircraft in each altitude layer and the approximate bearing of its ground track.

(4) Its own position in **a** distinctive manner.

(5) Specific and hazardous weather information in the zone covered by the display.

(6) Temporary hazards to flight including unequipped aircraft when this data are available on the ground.

(7) General clearances and information to all aircraft within a particular volume of airspace.

b. **The** Symbolic Display (Equipment No. l(b)) shall display within the aircraft:

(1) All traffic control clearances relating to the aircraft in which the display is installed.

c. The **rate of** transmission of these **displays** to the aircraft is listed under the functional characteristics of the ground facility being used.

3. Proposed Location

Situation display shall **be** located in the cockpit so as to be visible to the pilot (and to second pilot if the aircraft carries more than one pilot).

4. Relation to Other Equipment

The pictorial and symbolic display shall be located near each other. Pictorial information is **received** over the navigation air-ground link. The data for symbolic display arc received over the private line link.

5. Weight and Volume

Display equipment shall be designed to fit all types of aircraft.

6. Frequency Coverage

See Section III, Part F.

D. TRAFFIC DATA RELAY EQUIPMENT (Ground - Equipment No. 3)

SECONDARY RADAR - REQUIREMENTS FOR THE ULTIMATE SYSTEM

1. Objective

To determine automatically the three-dimensional position of all aircraft withtn range which carry the traffic control equipment and register their identities.

2. Functional Characteristics

The equipment shall be capable of:

a. Interrogating all aircraft at ranges **up** to 115 miles, within propagation line of sight, and **determining** their plan position (with **an** accuracy of one-half mile in bearing and one-**quarter** mile in range at a distance **of** 45 miles).

b. **Rotating** at as high a rate as practicable but at least at a rate of 15 revolutions per minute.

c. Giving the same vertical coverage as the primary surveillance radar (or within the limits **imposed if** the frequency of the two is different).

d. **Determining** the true altitude of an aircraft with an accuracy of ± (100 feet ± 1/2% of true **altitude)** at distances of 45 miles or less at altitudes above line-of-sight.

e. Feeding positional information as outlined stove to automatic air traffic control equipment **Number 4.**

f. Supplying positional information and identity for use in the pictorial portions of the General **and Airport** Area Displays.

g. **Being slaved** to the surveillance **radar and** using the same antenna pedestal.

(1) When used with a precision radar (such as precision GCA) the secondary **radar, in** cooperation with the airborne traffic control equipment, shall also meet the following Performance requirements:

(a) The angular size in bearing and elevation of the traffic control equipment responses displayed shall not exceed the angle represented by the bearing and elevation beam-widths measured at the half-power points for one-way trans**mission.**

(b) The angular displacement between the primary radar echo and the traffic control equipment response shall not exceed 1/8 of the precision radar antenna beam**width measured** between the half-power points for'one-way transmission. This permissible displacement shall include any error brought about by the placement **of the** airborne antenna and shall be met down to ranges of 1/2 mile.

(2) When used with primary surveillance radar, the secondary radar, in cooperation with the airborne traffic control equipment, shall also meet the following performance re**quirements:**

(a) The angular size, in bearing, of the traffic control equipment responses displayed shall not exceed the angle represented by the bearing beam-width measured at the half-power points for one-way transmission. This requirement and the one in the following paragraph shall be met for input signals to the traffic control equipment as high as 3600 times the input power required for triggering. Furthermore, both the requirements in this and the following paragraph shall be met for the minimum radar antenna rotational speeds.

(b) The angular displacement between the pritnary radar echo and the traffic control equipment response shall not exceed 1/6 of the surveillance radar antenna beam-width measured between the half-power points for one-way transmission.

(c) The system shall operate down to at least 1/2 mile distance at an altitude of 1000 **feet.**

3. Proposed Location

a. Complete area coverage secondary radars will be located so as to serve all terminal areas **and** all major airways including buffer area coverage outside of the defined areas.

b. Secondary Radar Interrogators without associated primary radars may be located on low-density airways and at remote off-airway points to effect spot position determination in low density areas and to provide navigational checks to aircraft.

4. Relation to Other Equipment

This equipment is the link between the airborne traffic control equipment and automatic traffic control equipment.

5. Frequency Coverage

See Section III, Part F.

SECONDXRY RADAR - REQUIREMENTS FOR THE INTERIM SYSTEM

All of the above requirements apply to the interim equipment as found practicable except that the permissible accuracy shall be such as to locate an aircraft with an accuracy of $\pm$ 1 mile in bearing and 1/2 mile in distance at 3 distance of 45 miles.

PRIVATE LINE - **REQUIREMENTS FOR THE ULTIMATE SYSTEM**

1. Objective

The purpose of this equipment is:

a. **To provide** an air-ground private line (addressed) communication.

b. To accomplish "a" above in limited channel equipment.

2. Functional Characteristics

a. **The** private line shall provide for the automatic, fail-safe, transmission of air traffic con**trol** information (clearances, requests, confirmations, etc.) between aircraft and the ground. This shall include the ability to receive air-derived navigational information from the aircraft.

b. It shall be possible to display the intelligence received over the private line in a suitable **manner** for monitoring by the control operator.

c. The private line shall be capable of feeding the information listed in "a" above directly **into** the airspace separation and flow control elements (4a. and 4b).

d. By use of this equipment, it shall be possible to communicate with aircraft in blocks of airspace of some five miles square and 1000 feet vertical thickness without knowledge of the aircraft identities and without requiring cooperation of the aircraft's navigation equipment.

3. Proposed Location

Private line ground equipment shall be installed at the sites of the secondary radar interrogators.

4. Relation to Other Equipment

a. The ground private line element receives traffic control requests, confirmations, etc., . from the airborne traffic control equipment. It also receives the readings of the aircraft's navigation instruments. (R, Θ, H position reports.)

b. The private line element sends to the flow control equipment, through the airspace separation equipment, the information listed in "a" above.

c. The private line element receives traffic control information, clearances, confirmations, etc., from the flow control element through the airspace separation element and forwards them to the appropriate aircraft.

5. Frequency Coverage

See Section III, Part F.

PRIVATE LINE - REQUIREMENTS FOR THE INTERIM SYSTEM

1. Objective

Same as for "Ultimate Requirements".

2. Functional Characteristics

Same as for "Ultimate Requirements" except for the requirement that it be capable of communicating with a fixed unit **of** airspace without knowledge **of** the aircraft's identity and without requiring the cooperation of the aircraft's navigation equipment.

3. Proposed Location

Same as for "Ultimate System".

4. Relation to Other Equipment

Same as **for** "Ultimate System".

5. Frequency Coverage

See Section III, Part F.

E. AUTOMATIC AIR TRAFFIC CONTROL EQUIPMENT [Ground - Equipment #4)

AIRSPACE SEPARATION ELEMENT (Equipment #4a)

1. Requirements **for** the Ultimate System

a. Objective. To prevent two or more aircraft from occupying any particular unit of air**space** at the same time and to prevent aircraft **from** entering dangerous areas such as **those** which contain fixed obstacles.

b. Functional Characteristics. The equipmen: must satisfy the following functional requirc- ments:

(1) It shall be capable of utilizing the positional data obtained by other ground equipment to determine and register occupancy of airspace.

(2) It shall be capable of interlock operation so that aircraft cannot be cleared into occupied units of airspace but will be readily cleared into unoccupied units of airspace.

(3) It must be capable of automatically furnishing clearances and information derived, as in (2) above.

(4) It must be able to convey the positional data and pilot requests and reports to the flow control clement.

(5) It must be able to monitor the clearances given by the flow control equipment to insure that they do not allow dual or hazardous occupancy of airspace.

c. Proposed Location. This equipment shall be used along all airways where the traffic density is such that separation by time intervals is unsatisfactory.

d. Relation to Other Equipment. This equipment provides the link between the private line plus the occupancy determining equipment (secondary radar or position reporting portion of the private line when these are not available) and the flow control equipment.

2 . Requirements for the Interim System

a. Objective. Same as for "Ultimate Requirements".

b. Functional Characteristics. Same as for ultimate system except that in the interim, manually operated interlocks should be used wherever operationally feasible and traffic density warrants.

C. Proposed Location. Same as for "Ultimate Requirements".

d. Relation to Other Equipment. In the interim, occupancy information will be gathered from interim secondary radar system and aircraft position reports and inserted in the interim manual interlock equipment by controllers. The clearances derived from the manual interlock equipment will be transmitted from the controller to the pilot over the normal voice communication channels.

FLOW CONTROL ELEMENT (Including Navigational Report Checking Function - Equipment # 4b)

1. Requirements for the Ultimate System

a. Objective. To achieve expeditious flight of aircraft with full use of runways and airways. It is also a purpose of this equipment to check the navigation position reports.

b. Functional Characteristics. The functions of this equipment are closely allied to those of the Flight Path Planning Element #4(c), and these equipments may be combined. The flow control element shall meet the following functional requirements:

(1) It shall receive position reports and pilot requests through the Airspace Separation Element #4(a).

(2) It shall check the ground determined position data against the previously established plan of operation to insure that any deviations will not excessively slow up traffic and to insure that deviations will not cause later blocking of the flow by the separation system.

(3) It shall send clearances to the Airspace Separation Element concerning preferred operations of aircraft.

(4) It shall compare the reports of the air-derived navigational information and compare these reports with the occupancy data which are ground-derived. It shall then report any significant deviations to the pilot via the private line equipment.

C. Proposed Location. Complete equipment will be located only in busier genera1 areas. Partial equipment, to assist traffic control operators, may be in medium density areas.

d. Relation to Other Equipment. The flow control equipment receives information from the Flight Path Planning Element #4c, from the position determining elements, and from the private line element. It organizes this information and sends clearances to the private line element (always subject to override by the Airspace Separation Element).

2. Requirements for the Interim System

a. Objective. Same as for "Ultimate Requirements".

b. Functional Requirements. In order to give some early assistance to control in crowded areas, a simplified flow control element automatically receiving spot reports should be evolved, leaving the problem of resolving anticipated conflicts to the control operator.

c. Relation to Other Equipment. Receives spot position reports via the private line, voice channel, or from the secondary radar and warns controller of deviations from existing flight plans.

DISPLAY FOR USE BY DETAIL FLOW CONTROL UNIT (Pictorial - Equipment #4e)

1. Objective. To provide pictorial display of air traffic situation information for those parts of the General Control Area, as required.

2. Functional Characteristics

a. This display shall present information as to established lanes in the terminal and portions of the enroute areas, as required. Also, it will show reference planes and location of airports and obstacles.

b. Information concerning each aircraft shall show:

(1) Plan position.
(2) Altitude.
(3) Approximate bearing of the ground track.
(4) Identity, automatically, on request.

c. Associated with the display shall be means for inserting data as may be required.

3. Location of Equipment. The display equipment, where required, shall be closely associated with the symbolic display in General Control Area offices.

4. Relation to Other Equipment. Pictorial information displayed shall be received from:

a. Secondary radar.
b. Automatic traffic control equipment.
c. Manual insertions.

DISPLAY FOR USE BY DETAIL FLOW CONTROL UNIT (Symbolic - Equipment #4e)

1. Objective. To provide a display board which presents to operators of the Detail Flow Control Unit, within General Control Area office continuous symbolic information or. groups of aircraft operating in the respective General Control Area. The information shall include current and proposed position data on individual aircraft.

2. Functional Characteristics

a. Display board shall be in a vertical plane of limited size for operators to use from a sitting position.

b. The equipment shall be constructed in sections to provide for expansion.

c. Each section shall provide means for indicating:

(1) Detail flight plan data on individual aircraft for all aircraft operating in a select portion of the General Control Area. This information shall include current and proposed positions of aircraft.

(2) Detail information concerning points which define lanes and specific flight paths.

d. The providing of sufficient sections to present positions of all aircraft operating in the area at one time is not required.

e. Means shall be provided for selecting desired display of data for any portion of the General Control Area.

f. Means shall be provided to present aircraft positions and flight paths simultaneously to two different General Control Area offices or General Control Area office and Airport Control Area office concerned as may be required for coordination.

g. Means shall be provided to present differences, outside of established tolerances, between positions of atrcraft as obtained by the automatic air traffic control equipment and positions of the same aircraft as derived frotn the airborne navigation equipment.

h. Means shall be provided to present distinctive display of discrepancies that occur. These include variance from established tolerance and deviation of aircraft from assigned flight path including position.

i. Means shall be provided for manual insertion in the automatic air traffic control equipment for establishing flight paths, issuing clearances, and displaying of data:

(1) For introducing aircraft into the system.
(2) If aircraft equipment fails.
(3) If parts of air traffic control equipment fail.
(4) For allowing aircraft to operate in the system in any safe manner as may be required by operational considerations.

j. Provision shall be made for showing, simultaneously, a discrepancy in position or emergency of aircraft when it occurs with associated information on other aircraft and flight paths as will be required.

k. An indicator for each symbol should be of sufficient size for ready reference by the operator. Indications should be properly organized for each aircraft and group of aircraft for a specified portion of the area.

3. Proposed Location. Each General Control Area office shall be provided with the proper number of display board sections.

4. Relation to Other Equipment

a. Information symbolic display sections shall be closely associated with pictorial situation display where provided for Detail Flow Control Operator's use.

Further, the Detail Flow Control displays should be in the same office with the General Planning display.

b. Information displayed shall be received from:

(1) Air traffic control and navigation source.
(2) Automatic air traffic control equipment.
(3) Manual insertions, as required.

FLIGHT PATH PLANNING ELEMENT (Equipment #4c)

1. Objective. To provide a means whereby an operator can determine a tentatively safe route for an aircraft to follow during a certain period of time. Choice of this route should insure progress without delay. This equipment may be combined with the flow control element associated with the remainder of the automatic traffic control equipment.

2. Functional Characteristics. This equipment is a computer having three functions as follows:

a. It is a computer intu which an operator can insert for all aircraft takeoff time, speed of aircraft, desired lane (altitude and track), and determine that, so far as known data are con-

cerned, a conflict between flight plans will not occur.

b. **After** the operator has determined a non-conflicting optimum path, that path will be registered (stored) within the machine for the time that the route will be used.

c. After the path is registered, the equipment contains within it the information concerning the desired position of the aircraft. This information may be used for comparison with the time position of the aircraft in the next succeeding air traffic control equipment which comparison can result in the prediction of collision and is used as the basis for issuing flow control information.

3. Technical Considerations

a. The equipment is made ready to operate by manually inserting into it the following information (constants):

(1) Wind direction and speed for all altitudes for the entire zone.

(2) Usable lanes or portions thereof (determined by weather and other factors).

b. In making the route plan, the route plannin, operator inserts into it the following:

(1) Identity of aircraft.
(2) Takeoff time or time of entry into zone over which the center has cognizance.
(3) Speed of aircraft.
(4) Preferred lane (altitude and track).
(5) Destination if within zone or point of exit from zone.

c. The foregoing information shall always be entered into the equipment in the same sequence.

d. The equipment selects a track at or near the preferred altitude where conflict will not occur.

e. After the equipment has selected a lane, the information is conveyed to the operator.

f. **If the** operator accepts the equipment's lane selection, the flight plan is stored within the equipment.

g. After the flight plan time lapses, the recorded information disappears from storage.

h. Flight plans may be cancelled or altered prior to the time they are to lapse in order to provide for changes.

i. It is not to be interpreted that requested flight plans shall consist only of parallel tracks. Routes incorporating changes in altitude and tracks shall be possible with this equipment.

j. **If after a** flight plan is registered within the equipment, the flight path planning element **of the** following equipment determines that an excessive or hazardous deviation from the **plan has occurred,** it shall recompute a safe and expeditious flight path for the particular **aircraft and** make sure that this new path is compatible with all other existing flight plans. In low traffic areas, the human controller may well accomplish this without aid. In medium density traffic, some simple form of computer may be required to assist him. In the **high density** areas, completely automatic computers may be required.

k. **It shall be capable** of being over-controlled, either in whole or in part, by the control operator to take care of general or special emergencies.

l. **It shall handle at least 60** movements per live runway per hour (for example, 30 landings **and** 30 takeoffs).

m. **It shall handle** a maximum of at least 100 to 125 planes simultaneously.

n. It shall be capable of being simplified to handle less traffic in less dense areas.

o. **It shall** handle the landing paths for at least six live runways in an area fed bv at least six **enroute airways.**

p. In case of failure (equipment failure, blocked runway, etc.), the flow control element shall compute new flight paths for all aircraft within one minute.

q. The equipment shall be expandable to accommodate the number of altitudes and tracks operationally required along a given route.

r. One equipment per route will be required.

s. The equipment will be located at General Area Traffic Control offices.

4. Performance Requirements

a. The length of time required from the entering of a proposed flight plan until a reply is received shall not exceed two seconds.

b. The length of time required from the instant the operator indicates a plan is to be registered (stored) until this action is completed shall not exceed two seconds.

c. The equipment after having set into it manually the required constants shall be capable of unattended operation.

AIRPORT TIME UTILIZATION ELEMENT (Equipment #4d)

1. Objective. To provide means for the full operational utilization of terminal facilities such as landing runways, taxi areas, etc.

2. Functional Characteristics. This portion of the Automatic Air Traffic Control Equipment shall be capable of receiving from teleprinter circuits the requests for specific right to land at the airports involved and the desired landing times. It shall be capable of granting the requests, denying the requests, or offering an alternate plan.

3. Tentative Technical Considerations

a. Each landing time reservation section shall be designed for a single airport and be capable of functioning with all the units necessary to take care of the number of airports within a given terminal area.

b. It shall be capable of having set into it the following information:

(1) Number of aircraft that the specific airport to which the machine applies can accept per unit of time.

(2) The time reserved in advance by number of arrival and departure times, per class of aircraft, and takeoff terminals.

(3) Percentages of types of traffic that will be accepted by class.

c. Available acceptance time will be allocated by route, class of aircraft, and distance from which flight originates. If reservations are not made to such an extent as to use all available time allocated to each of the above subdivisions, the equipment shall automatically make this time generally available for use irrespective of route, class of aircraft, or distance from which flight originates.

d. Means shall be provided whereby the requesting station of origin or destination can cancel a reservation.

e. The equipment shall be capable of receiving communication inputs from a number of traffic origin and destination centers.

f. The communication input will consist of a teleprinter five-unit code giving the following:

(1) Area originating request
(2) Class of aircraft
(3) Identity of aircraft
(4) Destination desired
(5) Landing time desired

g. Upon 'receipt of the communication, the equipment shall determine whether or not a landing time is available and:

(1) Establish and store the time reservation in the name (number) of the aircraft, or

(2) Determine an alternate landing or takeoff time, or

(3) Determine an alternate landing terminal, or

(4) Determine that request cannot be met within an established reasonable period of time.

h. Action taken in either steps (I), (2), (3), or (4) of g. shall be transmitted automatically to station originating request.

i. A display is required at the point where the Airport Time Utilization Equipment is located. It shall include the following:

(1) Unreserved spaces shown in terms of hours, airports, and class of aircraft.

(2) Warning lights shall be associated with each of the above subdivisions of the display to indicate what parts of the available space have been reserved.

(3) A means of checking the operation of the Airport Utilization Time Equipment shall be provided. One possible provision would be the feeding in of standard data from a tape; after determining that proper operation resulted, the data fed in could be cancelled.

j. The time capacity of the machines shall be at least 24 hours.

4. Location. Location of the equipment is a function of the operations communications line rental and the location of the cognizant agency.

5. Performance Requirements

a. This equipment shall be capable of operation from great distances which dictates the use of a type of transmission the quality of which shall not deteriorate with distance.

b. The equipment shall be capable of operations with input keying speeds equivalent to 60 words per minute, capable of being raised to 75 if required.

c. After the equipment has had set into it manually the required constants, it shall be capable of unattended operations.

DISPLAY FOR GENERAL PLANNING UNIT (Symbolic - Equipment #4f)

1. Objective. To present to operators of the General Planning Unit within the General Control Area office symbolic information on groups of aircraft which will arrive at or depart from airports within the General Control Area. This shall include the General Planning situation and information for monitoring and approving requests for acceptance times.

2. Functional Characteristics

a. The display board shall be in a vertical plane and of limited size for the operator to use from a sitting position.

b. The equipment shall be constructed by section to provide for expansion.

c. Each section shall provide for indicating:

(1) Detailed acceptance planning information on all aircraft for which acceptance limes have been reserved over a selected period. This information shall include acceptance times reserved and acceptance times still available for each airport.

(2) Detailed acceptance planning information on aircraft requesting acceptance time

reservations. This information shall include such items as identity, system number, type, originating point, and acceptance time requested.

d. The providing of sufficient sections to present all acceptance times reserved and available in the area at one time is not required.

e. Means shall be provided for selecting the display of data for any desired period.

f. Means shall be provided to present distinctive display of requests for acceptance times which conflict with previously reserved times or previously established standards.

g. Means shall be provided for manual control of the landing time reservation equipment for reserving acceptance times which require special handling.

h. Means shall be provided for approval of the reserved acceptance for transmission to the originating point.

i. An indicator for each symbol should be of sufficient size for ready reference by the operator. Indicators should be properly organized for each aircraft and group of aircraft for the specified period displayed.

3. Proposed Location. Each General Control Area office shall be provided with the proper number of display board units.

4. Relation to Other Equipment

a. The General Planning Display shall be closely associated with the Detail Flow Control display (equipment #4(e)) in the General Control Area office.

b. The information displayed shall be received from the Airport Time Utilization element (equipment #4(d)), the originating points, and manual insertions as required.

F. NAV-AID EQUIPMENT (Ground - Equipment No. 5)

1. Objective

To furnish to the aircraft the information required for navigating in the enroute zone (on or off the airways), initial approach zone, and holding areas. This ground equipment also provides the transmitting link for a situation display of the area and a transmitting and receiving means for aural communication,

2. Functional Characteristics

a. The navigational information, situation display, and aural communications in an area shall be transmitted to the aircraft over one assigned channel.

b. Navigational information shall be in polar coordinates.

(1) The ground equipment shall originate and transmit the signals required for use in the airborne receiver for determining the bearing of the aircraft with respect to the ground site.

(2) Upon interrogation by the airborne equipment, the ground transmitter will reply with the signals required for use in the airborne equipment for determining the distance of the aircraft from the ground site.

(3) The equipment at each site shall provide complete navigational information to 311 points within a radius of 115 statute miles at usable line of sight altitudes and within a radius of 45 miles down to and including 1,000 feet above the terrain.

(4) The overall accuracy of the navigation system, including the airborne equipment errors, shall be $\pm$ 0.6 degrees in bearing and $\pm$ 0.2 miles or 1 percent, whichever is greater, in slant range for distances up to 113 statute miles from the facility. Ninety-five per cent of all determinations shall not be in greater error than that specified when based on Gaussian distribution.

(5) At distances up to 45 miles from the facility, the indications within the aircraft shall be sufficiently sensitive to delineate between positions separated by 1/10 mile or less.

(6) As an immediate objective, the system shall provide corrected navigntional information in the aircraft at a rate not less than one per second.

(7) The ground equipment shall accommodate at least 500 aircraft simultaneously without a reduction in the aircraft or ground equipment performance including system accuracy.

(8) The ground navigation facility shall be continuously identified by automatic voice and code.

(9) The system shall have a minimum susceptibility to jamming.

(10) In case of malfunctioning of the equipment, pilots and appropriate ground personnel shall be automatically warned. The warning shall be in a form which cannot be inactivated by human intervention.

(11) The cone above the ground facility within which the signals to the aircraft are absent or indefinite shall not exceed 30 degrees apex angle.

(12) A marker transmitter shall be provided for the purpose of defining the above cone so that aircraft can check the accuracy of airborne distance indications. These marker transmissions shall be receivable by an aircraft not carrying the airborne transmitter portion of equipment number two above. The marker transmitter shall be capable of separate installation as required.

c. The ground equipment shall provide the transmittin, link to the airborne receiver for the signals used in the situation display.

(1) Immediate objective shall be for the transmission of the situation display information at a rate greater than one complete picture every minute.

(2) The area of reception coverage shall be the same as the navigntional aid being used.

d. The system shall be capable of transmitting and receiving air-ground communications by non-automatic means.

(1) Voice communication from ground to air and air to ground over this facility shall be provided without a reduction in the performance of the navigational or situation display transmission functions of the facility.

(2) Only one air to ground and one ground to air channel need be provided at each facility.

(3) The area of coverage by the communication means shall be at least the same as the navigational coverage for the same facility.

(4) This communication link provides a standby navigational and traffic control facility with the aid of ground personnel.

3. Proposed Location

a. The ground equipment required for any specific area of coverage shall be located on a single site. This site shall be not larger than 600 feet square.

b. The ground equipments used for furnishing navigational information along the airway shall be so spaced that there is an overlap in each lane of the airway in the coverage of the adjacent facilities.

4. Relation to Other Equipment

a. The ground equipment at each site shall develop navigation information for all aircraft within its zone of coverage independently of the operation of the equiptment at any other site.

b. The ground equipment shall provide a means for transmitting the situation display and transmitting and receiving aural communications together with the navigational information. The situation display information and the voice communication will be connected to this ground equipment over land-lines or micro-wave radio links from other ground equipments described in this report.

c. During the interim period when more than one system of navigational aids may be required to operate simultaneously, components of the system specified herein shall be so designed, sited, and operated that interference cannot result to the performance of either system,

5. Frequency

a. See Section III, Part F.

b. Frequency shall be stabilized to ± 0.01% or better.

G. LANDING NAVIGATION AND MONITORING EQUIPMENT (Equipment No. 6)

LANDING MONITORING EQUIPMENT (Equipment No. 6a)

1. Objective

To furnish to the airport control unit means for:

a. Monitoring the approach and landing of aircraft which is using the airborne navigational and traffic control equipment.

b. Providing an approach and landing aid in conjunction with aural or private line communication.

2. Functional Characteristics

a. The ground monitoring equipments shall provide indications of bearing, elevation, and distance of an aircraft from the touchdown point for all distances out to at least 15 miles along the approach path on an aircraft with a reflecting surface area of one square meter or greater, without airborne beacon assistance. The angular coverage shall be at least 10 degrees above the horizontal in the vertical plane and ± 10 degrees in the horizontal plane, as measured from the approach path. So coverage is required for elevations below 1/2 degree above the horizontal, as measured from the approach end of the runway.

b. The accuracy of the monitoring function of the system shall be not less than the basic bearing guidance, landing slope, and distance indication to the aircraft of the Nav-Aid Equipment.

c. The personnel requirements for the ground visual monitor function and emergency aid function shall not exceed one man per watch or working period.

d. The equipment shall provide a means for monitoring the departure of an aircraft from a runway. The equipment shall have a range of at least 6 miles on the departure path. The azimuth and elevation coverage shall be the same as that used for the approach and landing coverage.

e. The monitoring equipment shall provide means for remote display.

3. Proposed Location

a. The ground equipment shall be installed for operational use within the airport area.

b. The ground equipment shall offer no obstruction to aircraft landing or departing in the proper approach and landing areas.

4. Relation to Other Equipment

a. The ground equipment shall provide the necessary aural and visual communication links to other equipments where required.

b. Ground receiving equipment for accepting coded returns from an airborne transponder and. private line equipment in the aircraft in the approach and landing areas shall be provided when required.

c. During the interim period when more than one system of navigational aids and monitoring means may be required to operate simultaneously, components of the system specified herein shall be so designed, sited, and operated that interference to the performance of either system will not result.

d. This equipment may be combined with the Landing Navigation Equipment No. 6b.

5. Frequency Coverage

See Section III, Part F.

LANDING NAVIGATION EQUIPMENT (Includes Departure Navigation Equipment - Equiptment No. 6b)

1. Objective

To furnish to the aircraft the navigation information required for landing on a predcter-mined runway and provide the transmitting link for a situation display of the area being used and a transmitting and receiving means for aural communication.

2. Functional Characteristics

a. The navigation information used for final approach, landing, situation display, and aural communications in a final approach and landing area shall be transmitted over one channel assigned to that area. These functions may be performed simultaneously, on a time sharing basis, or by the use of other techniques, providing the requirements of each function as outlined herein are met.

b. The System shall provide approach and landing paths to all runways on the airport which are suitable for all weather use.

(1) The System shall provide continuous visual indication of the position and heading of the aircraft relative to the optimum flight path.

(2) The System shall provide continuous visual indication of the distance of the aircraft from the touchdown point on the runway.

(3) The System shall provide continuous visual indication of the position and rate of deviation of the aircraft relative to the optimum landing slope.

(4) The System shall be capable of providing for either automatic or manual fiight to a landing.

(5) The System shall permit simultaneous final approaches and landings on multiple runways.

(6) The System shall not be the limiting factor in the determination of the traffic handling capacity in the final approach area and airport.

(‘7) The System shall automatically and radically change the character of its indication, both in the air and on the ground, in case the divergence from proper alignment remains outside the safe tolerance for the particular installation.

(8) The System shall provide immediate and positive indication of malfunctioning of the ground equipment to the appropriate ground control.

(9) The same facilities which are used in the final approach area, with the exception of the landing slope information, shall be used in the departure area.

(10) The Equipment shaI1 have a minimum susceptibility to jamming.

(11) The System shall be capable of providing navigational information for aircraft pull-outs.

(12) The System shall be readily indcntifiable as to airport and runway.

(13) The following requirements are listed as immediate objectives:

(a) The System shall be capable of accommodating at least 50 aircraft without a reduction in the aircraft and ground equipment performance and system accuracy and have a landing rate capacity equal to that required for military operations (at least 3 per minute),

(b) Indication in the aircraft of bearing guidance and distance shall be provided to at least 25 miles on the approach path and to at least 6 miles on the reciprocal landing or departure path.

(c) Positive indication as to the proper course to fly or heading to assume and the distance from the touchdown point shall be provided to at least 20 degrees on both sides of the center line of the approach path, measured from its point of origin. This coverage shall also be provided on the reciprocal landing or departure path.

(d) Indications to the pilot shall include quantitatively displacements at least up to ± 5 degrees in the position to the right or left of the center line of the approach path.

(e) Any displacement of the aircraft in the horizontal plane of the order of 1/4 degree to the left or right of the center line of the approach path, measured from its point of origin, shall give an indication readily discernible by the pilot.

(f) Indications to the pilot shall include quantitatively displacements of at least up to ± 1/2 degree in the position above and below the path slope.

(g) Any displacement of the aircraft in the vertical plane of the order of 1/20 degree above or below the path shall give an indication readily discernible by the pilot.

(h) Above the horizontal, coverage for bearing guidance in the vertical plane shall be provided between the angles of 1/2 of one degree, measured from the approach end of the runway and twenty degrees, measured from the opposite end of the runway. This coverage shall also be provided on the reciprocal landing or departure path.

(i) Indication of the approach end of the runway, or a safe let-down area, shall be provided in the aircraft. This position indication shall have an accuracy of ± 200 feet.

(j) The displacement information shall be free of false courses within the area of ± 60 degrees of the center line of the approach and landing path.

(k) The elevation guidance information to the aircraft shall be free of false courses at all angles less than three times the maximum normal slope plane.

(l) The inclination of the optimum path above the horizontal at distances between 2500 feet and 15 miles shall be capable of being set and fixed on the ground at any angle between 1 3/4 and 4 degrees. A flare-off shall be provided which will change the path angle from the normal inclination to 1/2 of the normal inclination for all distances less than 2500 feet from the point where the path intersects the ground.

(m) The distance to the touchdown point shall have an accuracy of 0.2 miles or ± 1%, whichever is greater.

(n) The accuracy of the azimuth information of optimum, path shall be within ± 1/4 degree.

(o) The accuracy of the elevation angle of the optimum path shall be within ± 1/20 degree.

(p) Indication of the landing slope shall be provided out to at least 15 miles.

(q) Coverage of the landing slope shall bc provided to at least 8 degrees on each side of the landing path in the horizontal plane.

(r) Positive indication as to whether the aircraft is below or above the landing slope shall be provided between the angles of 1/2 degree below and 5 degrees above the horizontal, as measured from the point of origin.

c. The ground equipment shall provide the transmitting link to the airborne display.

(1) The transmission of the signals for the situation display in the aircraft shall be at a **rate** greater than one complete picture every 2 seconds.

(2) The area of coverage shall be the same as the navigation aid coverage.

d. The System shall be capable of transmitting and recciving,air-ground communications by non-automatic means.

(1) Voice communication from ground to air and air to ground over this facility shall be provided without 3 reduction in the performance of the navigation and situation display transmission functions of the facility.

(2) Only one air to ground and one ground to air channel need be provided at each facility.

(3) The area of coverage by the communication means shall be at least the same as the navigational coverage from the same facility.

(4) This communication link provides a standby navigational aid traffic control facility with the aid of ground personnel.

3. Proposed Location

a. The ground equipment shall be installed for operational use within the airport area.

b. The azimuth guidance, landing slope, and distance equipment on the ground shall be located near the point of contact.

c. The ground equipment shall offer no obstruction to aircraft landing or departing in the proper approach and landing areas.

4. Relation to Other Equipment

a. The ground equipment at each airport shall provide naviyation information for all aircraft using the system within the area of coverage indcpendcntly of the operation of equipment on any other airport.

b. The ground equipment shall provide 3 means **for** transmitting,the situation display and transmitting and receiving aural communications together with the landing navigational information. The situation display information and voice communication signals will be connected to this ground equipment over land-line or micro-wave radio links from other ground equipments described in this report.

c. During the interim **period** when more than one system of navigational aids may be re**quired** to operate simultaneously, components of the system shall be so designed, sited, and **operated** that interference to the performance of either system will not result.

5. Frequency Coverage

See Section III, Part F

H. AIRPORT SURFACE NAVIGATION AND MONITORING EQUIPMENT (Equipment #7)

AIRPORT SURFACE MOVEMENT EQUIPMENT (Equipment #7a)

I. Objective

To provide ground personnel with information concerning the location of aircraft and vehicles in the controlled areas on the airport.

2. Functional Characteristics

a. The equipment shall provide complete information as to the position of aircraft and 'vehicles in the controlled areas of the airport without airborne equipment assistance.

b. The equipment shall provide means for remote display.

3. Operational Factors

a. The taxi area is the principal limiting factor in traffic control when satisfactory navigation and traffic control means are in operation in the other areas.

b. The airport area is divided into controlled and uncontrolled areas. All vehicles which are used in the controlled areas shall carry (at least) the minimum equipment required for navigation and traffic control.

4. Proposed Location

a. The ground equipment shall be installed for operational use within the airport area.

b. The ground equipment shall offer no obstruction to aircraft landing or departing in the proper approach and landing areas.

5. Relation to Other Equipment

a. The equipment may be combined with the Airport Surface Navigation Equipment #7(b).

b. The equipment may be used to supply some of the situation display information which is transmitted to aircraft and to the ground based traffic control facilities by the Airport Surface Navigation Equipment.

c. During the interim period when more than one system of navigational aids may be required to operate simultaneously, components of the system shall be so designed, sited, and operated that interference to the performance of other systems will not result.

6. Frequency Coverage

See Section III, Part F.

AIRPORT SURFACE NAVIGATION EQUIPMENT (Equipment #7b)

I. Objective

To furnish to the aircraft and ground vehicles the information required for navigating on tne ground in the airport area during all weather conditions and during conditions of heavy traffic density. This ground equipment provides the transmitting link for a situation display of the airport area and a transmitting and receiving means for aural communication when used with the airborne traffic control equipment.

2. Functional Characteristics

a. Navigation information shall be provided to aircraft and other vehicles for all operational areas of the airport, both on and off taxiways.

(I) The navigational information shall be provided by visual means. If an airborne equipment is required, the aircraft navigation equipment shall be used.

(2) The overall accuracy of the system shall enable aircraft to stay within prescribed path limits in the controlled areas.

(3) The accuracy of the ground equipment shall not be affected adversely by weather conditions and the presence of aircraft and vehicles on the surface of the airport.

b. The ground equipment shall provide a transmitting link to the airborne receiver for the information required in the airborne situation display.

(1) The rate of transmission of the signals for the situation display in the aircraft shall be greater than 1 complete picture every 5 seconds.

(2) The area of reception coverage shall comprise the controlled limits of the airport.

c. The system shall be capable of transmitting and receiving air-ground communication by non-automatic means.

(1) Voice communication from ground to air and air to ground over this facility shall be provided without a reduction in the performance of the navigational and situation display transmission functions of the system.

(2) Only one air to ground and ground to air channel need be provided at each airport.

(3) The area of coverage by the communication means shall be equal to at least the airport area.

3. Location

a. The ground equipment shall be installed for operational use within the airport area.

b. The ground equipment shall offer no obstruction to aircraft landing or departing in the proper approach and landing areas.

c. The system shall provide for the installation of necessary transmitting and receiving equipment in vehicles other than aircraft which are operating in the controlled areas on the airport.

4. Relation to Other Equipment

a. The ground equipment may be combined with the Airport Surface Movement Equipment +7(a).

b. The ground equipment shall provide for transmitting the situation display and aural communication signals over land-line or micro-wave radio links to other ground equipments as required.

c. During the interim period when more than one system of navigational aids may be required to operate simultaneously, components of the system shall be so designed, sited, and operated that interference to the performance of other systems will not result.

5. Frequency Coverage

See Section III. Part F.

I. AIRPORT UTILIZATION PLANNING AND CONTROL EQUIPMENT (Equipment #8)

1. Objective

To present information required by the operator of the airport control unit to enable him to monitor and control the flow of traffic within the airport control area.

2. Functional Characteristics

The airport display unit shall consist of the following:

a. Symbolic display (Equipments #8(a) and 8(b)) of data showing current and proposed position of aircraft including detailed information required for aircraft operating in the airport area and current rate of aircraft flow.

b. Pictorial display (Equipments #8(c), 8(d), and 8(e))

(1) Showing positions of aircraft in flight in the airport control area.

(2) Showing positions of aircraft and other vehicles moving on the airport surface and showing guide tracks set up for directing surface movements.

(3) Showing positions of aircraft on final approach path.

c. Manual control shall be provided for issuance of information and clearance as may be required.

3. Location of Equipment

This equipment shall be located in the airport control unit office.

4. Relation to Other Equipment

a. Symbolic display data shall be derived automatically from the Automatic Air Traffic Control equipment #4. In addition, provision shall be made for the manual insertion of data by the airport control unit operator.

b. Display data for the final approach path shall be derived from the landing monitor (equipment X6(a)). This information shall be re-transmitted to the aircraft for airborne landing display. This transmission may be time-shared with corresponding transmissions for the airport area and airport surface movement displays.

c. Display data for the airport area shall be derived from the secondary radar (equipment #3). Input to the display for airport surface movement shall be derived from the Airport Surface Navigation and Monitoring Equipment #7.

d. Inter-lock shall be provided with the Automatic Detail Flow Control equipment to safeguard occupancy of the Final Approach area.

J. INTERCOMMUNICATION EQUIPMENT (Equipment #9)

INTERPHONE EQUIPMENT

1. Objective

To establish the performance characteristics of an interphone system required for aural intercommunication between ATC centers, airline centers, weather bureau offices, air terminal control towers, and related units essential in the functioning of the Air Traffic Control system.

The interphone system may function as the primary means of intercommunication between ATC units in low density traffic areas and as a secondary communication means in areas where air-traffic density is high and control is achieved largely through automatic traffic control facilities.

2. Functional Characteristics

a. The System shall be capable of functioning over a voice telephone channel between selected stations.

b. Means to signal stations on the system shall be provided. Selective and multiple signaling functions shall be provided.

3. Detailed Technical Considerations

a. The interphone system shall provide an integrated means for full duplex voice telephone communication between two stations, among several stations, or among all stations within ATC area.

b. Extension of the interphone system through one or more ATC areas shall be possible.

c. The signal level at a receiving station shall be maintained substantially constant regardless of the station of origin in the System.

d. The selective signaling means shall function rapidly. Signaling shall involve an overall time delay which is small compared to the 20 second duration of the average communication.

e. Multiple switching positions shall be provided to expand the System as required to meet **the** needs of the ATC center.

AUTOMATIC ATC POINT-TO-POINT COMMUNICATIONS

1. Objective

This description applies to the type of ground communication equipment to bc used **between** Airway Traffic Control Centers, Airport Traffic Control Towers, and points along the route **of** the aircraft, and points within the area of the Airway Traffic Control Center.

2. Function

Communication shall be in telegraphic code over facilities which, in general, will be wire facilities.

3. Performance Characteristics

a. The communication system shall be based upon the use of a five-element telegraphic code. It shall operate to transmit aircraft flow information in a sequential manner and shall be capable of expansion in message capacity by **use** of coordinated facilities. Transmission characteristics of the communication system shall be such that they are reliable over any **distance** required by air traffic control coordination.

b. The communication system shall have a minimum speed of transmission **in** the range 200 to 300 characters per minute and anticipate a maximum rate of 600 to 700 characters per minute.

c. The equipment used for transmitting aircraft flow information shall be capable of selective message routing.

d. The errors introduced in the transmission of messages shall **not exceed** $\frac{\text{of } 1\%}{10,000}$ of the **total** numbers of characters transmitted.

e. The communication equipment shall be capable of storing messages until such time sa wire facilities are available for re-transmission. The storage aquipment shall be located at each transmitting or receiving point **associated with arcraft flow information**

MICROWAVE AND/OR COAXIAL CABLE POINT-TO-POINT RELAY CIRCUITS **(Ground)**

1. Objective

This section applies to the type of ground communication equiupment to **be used in the Automatic Air Traffic Control System for airspace separation flow functions. and for private line message relay. Communication will be between General Control Areas, General Control** Areas and Airport Control Areas, and General Control Areas and facilities along the airways **and at airports.**

2. Function

Communication shall be in pulse, CW and modulated CW forms including interphone and teletype circuits) and will be by radio in the UHF and SHF hands allocated = to this type of service or by coaxial cables.

3. Performance Characteristics

a. **The communication system shall have twenty-four [illegible] cycle band-width two-way channels** per circuit. It shall have provision to combine several of these channels so that pulses may be relayed, Band-width for pulse transmission will depend on private line requirements.

b. The minimum speed of transmission for pulses shall be in the range of 10,000 per second with an anticipated maximum of 100,000 pulses per second.

c. The relay equipment shall be capable of selective message routing.

d. An error-proof code shall be used in pulse transmission which has automatic repeat back facilities for closed-circuit checking of transmissions.

e. The relay equipment must be capable of storing messages at the transmission and reception ends of the relay circuits.

f. The micro-wave and coaxial cable point-to-point relay circuits shall bc capable of conveying synchronization pulses between the various ground stations in addition to the other functions.

NOTE: It is realized that micro-wave and/or coaxial cable point-to-point relay circuits used for other functions such as television, FM, etc. can also be used for the traffic control functions, providing sufficient channels and band-widths are available. If existing and proposed common carrier facilities prove inadequate for these functions, there may be sizeable additional frequency requirements for ground micro-wave relay stations. These requirements are in addition to those listed in Section III F. This may be true to a limited extent in any case since commercial facilities are not available in many areas.

K. GROUND PRIMARY SURVEILANCE RADARS

ULTIMATE REQUIREMENTS

1. Objective

To determine three-dimensional position information of all aircraft, including high speed aircraft, without cooperation of any airborne equipment.

2. Functional Characteristics. The equipment shall:

a. Determine azimuth of all aircraft with an accuracy of ± 1/2 mile at 45 miles.

b. Determine distance to an aircraft with an accuracy of ± 1/4 mile at 43 miles.

c. Determine the true altitude of an aircraft with an accuracy of ± (100 feet + 1/2% of true altitude) up to 45 miles distance and at altitudes above 1000 feet.

d. Display this information without interference by reflections from fixed objects (MTI or equivalent).

e. Display this information without interference by weather effects (cloud and rain reflections).

f. Feed suitable information into the ground situation display and into the picture modifier to permit plan position indicator display of all aircraft by altitude lamina on the ground and in the air.

g. Deliver output signals whose amplitude is substantially independent of the altitude of the aircraft and its distance from the ground stations.

h. The equipment shall detect targets of one square meter reflecting cross section at distances up to 45 miles.

i. The maximum distance to be covered by the radar shall be 60 miles.

j. The vertical angle of cover should be 60 degrees or more, if practicable. At the higher angles, the distance should extend to the limit of the useable airspace.

3. Location

This equipment shall be located so as to serve all terminal areas and all major airways.

4. Relation to Other Equipment

This equipment collects and feeds positional information to the Automatic Air Traffic Control Equipment #4.

INTERIM REQUIREMENTS

1. Objective

To determine positional information of unequipped aircraft and to handle aircraft whose **airborne** equipment is inoperative within a range **of** 60 miles.

2. Functional Characteristics. This equipment shall:

a. Determine azimuth of an aircraft with an accuracy of ± 1 mile at 45 miles.

b. Determine distance of an aircraft with an accuracy of ± 1/2 mile at 45 miles.

c. Display this information with a minimum interference from reflections from fixed objects (MTI or equivalent).

d. Display this information with a minimum interference from weather effects (cloud and **rain** reflections).

e. **Feed** suitable information into the ground situation display to permit plan position indicator display of unequipped aircraft.

f. **The** equipment shall detect targets of one square meter reflecting cross section at distances up to 45 miles and at verticals up to at least 25 degrees.

3. **Location**

This equipment shall be located so as to serve only major terminal areas and major airways in the most crowded traffic areas.

4. Relation to Other Equipment

This equipment furnishes positional information regarding aircraft which cannot respond **to** the secondary radar.

L. **AIR** TRAFFIC CONTROL SYSTEM SIMULATOR

1. Objective

To provide a means for proving the efficiency of the equipment components of the basic system by simulating traffic control problems using control inputs and outputs as they would occur in actual usage. A further objective is to provide operational training for control personnel in the use **of** new procedures and equipments for air traffic control.

2. Develooment

a. The functional characteristics of the electronic equipment of the automatic air traffic control system shall be reproduced in the laboratory by using final or development models of equipment. Radio transmission paths shall be simulated by suitable facilities, eg., wave **guides** or transmission lines. The flight movements of aircraft shall be simulated realistically, e.g., data on varying position, flight maneuvers, etc., may be introduced into the system by means of punched tapes **and** cards or other permanent programming means.

b. In addition to reproducing the functional characteristics, means shall be provided in the **laboratory** to **check** the actual achievement of the control function by direct and recorded pbservations.

c. The simulation of air traffic shall include all of the variable elements normally experienced, e.g., speed, maximum number of aircraft anticipated subject to flow control, unequipped aircraft and equipped aircraft with partial or complete failures of apparatus, and personnel errors.

d. Each electronic facility envisioned in the complete traffic control system shall appear in the simulating setup. Flexibility in arranging the setup shall be provided in order that laboratory analysis of a multiplicity of traffic control problems may be made and to provide training for control personnel on varied problems.

e. The functioning of automatic control computer elements of the system shall not be compromised in establishing the simulating system.

f. The equipments shall be capable of continuous operation and, in those cases where standby equipment is to be provided in the actual system, the simulated system shall also include standby equipment which shall become functional in case of failure.

APPENDIX !V

EXCERPTS FROM FINAL ACTS OF THE INTERNATIONAL TELECOMMUNICATION ASD RADIO CONFERENCES DOCUSIENT RELATING TO THE 1947 MEETINGSAT ATLANTIC CITY

Frequency band and Bandwidth Mc/s	Allocations to Services World-wide	Regional Region 1	 Region 2	 Region 3
960 - 1215 (255)	Aeronautical Radionavigation			
1215 - 1300 (85)	Amateur			
1300 - 1700 (400)	102)	1300 - 1600 (300)) Fixed) Mobile 103) 104) 1600 - 1700 (100) Aeronautical radionaviga- tion	1300 - 1660 (360) Aeronautical radionavigation 104) 1660 - 1700 (40) Meteorological aids (radio sonde)	1300 - 1700 (400)) Aeronautical radio- navigation) Fixed) Mobile
1700 - 2300 (600)	a) Fixed b) Mobile 105)			
2300 - 2450 (150) 106)	Amateur			
2450 - 2700 (250) 106)	a) Fixed b) Mobile 107)			
2700 - 2900 (200)	Aeronautical radionavigation 108)			
2900 - 3300 (400)	Radionavigation 109) 110)			
3300 - 4200 omitted by SC31 editorially				
4200 - 4400 (200)	Aeronautical radionavigation 111)			
4400 - 5000 (600)	a) Fixed b) Mobile			
5000 - 5200 (250)	Aeronautical radionavigation			
5250 - 5650 (400)	Radionavigation 112) 113)			
5650 - 8500 omitted by SC31				
8500 - 9800 (1300)	Radionavigation 116) 117)			
9800 - 10,000 (200)	a) Fixed b) Radio- navigation			
10,000 - 10,5000 (500)	Amateur			
above 10,500	Not allocated			

EXCERPTED NOTES

215 101) In the U.S.S.R., the band 1215-1300 Mc/s is allocated for the fixed service, primarily for relaying television.

216 102) In Region 2, the band 1300- 1660 Me/s is intended for an integrated system of electronic aids to air navigation and traffic control. Administrations of the other Regions should envisage the possibility of the future application of such a system on a world-wide basis.

217 103) In the U.S.S.R., the band 1300- 1600 Mc/s is allocated for the aeronautical radionavigation service.

218 104) In Region 2 and the United Kingdom, the use of the band ` 1365 Mc/s is restricted to surveillance radar.

219 105) In Regions 1 and 3, the meteorological aids service may be operated in the band 1700-1750 Mc/s

220 106) In Region 2, Australia, New Zealand, Northern Rhodesia, Southern Rhodesia, the Union of South Africa, the territory under mandate of Southwest Africa, and the United Kingdom, the frequency 2450 Mc/s is designated for industrial, scientific, and medical purposes. Emissions must be confined within the limits of ± 50 Mc/s of that frequency. Radiocommunication services operating within those limits must accept any harmful interference that may be experienced from the operation of industrial, scientific, and medical equipment

221 107) In the U.S.S.R., the band 2450-2700 Mc/s is allocated for the aeronautical mobile and the aeronautical radionavigation services.

222 108) The meteorological aids service may be operated in the band 2700-2900 Mc/s

223 109) The band 3246-3266 Mc/s is designated for racons.

224 110) In the band 2900-3300 Mc/s shipborne radar in merchant ships is confined within the band 3000-3246 Mc/s

225 111) In China, the band 4200-4400 Mc/s may be used for the fixed service, provided that harmful interference is not caused to the aeronautical radionavigation service.

226 112) The band 5440-5460 Mc/s is designated for racons.

227 113) In the band 5250-3630 Mc/s shipborne radar in merchant ships is confined within the band 5460-5650 Mc/s

230 116) The band 9300-9320 Mc/s is designated for racons,

231 117) In the band 8500-9600 Mc/s shipborne radar in merchant ships is confined within the band 9320-9500 Mc/s

100 The three regions into which the world has been subdivided for the allocation of frequencies are:

101 Region 1:

Region 1 includes the area limited on the East by line A (lines A, B, and C are defined below) and on tne West by line B, excluding any of the territory of Iran which lies between these limits. It also includes that part of the territory of Turkey and the Union of Soviet Socialist Republics lying outside of these limitsk, the territory of the ,Mongolian Peoples' Republic, and the area to the North of the U.S.S.R. which lies between lines A and C.

102 Region 2

Region 2 includes the area limited on the East by line B and on the West by line C.

103 Region 3

Region 3 includes the area limited on the East by line C and on the West by line A, except the territories of the Mongolian Peoples' Republic Turkey, the territory of the U.S.S.R., and the area to the North of the U.S.S.R. It also includes that part of the terri-tory of Iran lying outside of those limits.

The lines A, B, and C are defined as follows:

104 Line A.

Line A extends from the North Pole along meridian 40 degrees East of Greenwich to parallel 40 degrees North; thence by great circle arc to the intersection of meridian 60 degrees East and the Tropic of Cancer; thence along the meridian 60 degrees East to the South Pole.

105 Line B

Line B extends from the North Pole along meridian 10 degrees West of Greenwich to its intersection with parallel 72 degrees North; thence by great circle arc to the inter-section of meridian 50 degrees West and parallel 40 degrees North; thence by great circle arc to the intersection of meridian 20 degrees West and parallel 10 degrees South; thence along meridian 20 degrees West to the South Pole.

106 Line C

Line C extends from the North Pole by great circle arc to the intersection of parallel 65 degrees 30 minutes North with the international boundary in Bering Strait; thence by great circle arc to the intersection of meridian 165 degrees East of Greenwich and para-llel 50 degrees North; thence by great circle arc to the intersection of meridian 170 de-grees West and parallel 10 degrees North; thence along parallel 10 degrees North to its intersection uith meridian 120 degrees West; thence along meridian 120 degrees West to the South Pole.

107 The “European Area” is bounded on the West by the Western boundary of Region 1, on the East by the meridian 40 degrees East of Greenwich, and on the South by the para-llel 30 degrees North so as to include the western part of the U.S.S.R. and the territories bordering the Mediterranean, with the exception of the parts of Arabia and Saudi - Arabia included in this sector.

APPENDIX V

BIBLIOGRAPHY

1. A New Approach to Cockpit Layout (An Analytical Presentation)
   Commander T. D. Davies, Bureau of Aeronautics, U.S.N.
   (Reprint SAE Paper Oct. 2-4, 1947)

2. Discussion of Pictorial Versus Symbolic Aircraft Instrument Displays
   Aero. Medical Laboratory, August 4, 1947
   Army Air Forces, Headquarters, Air Materiel Command

3. Recommendations for Safe Control of Expanding Air Traffic, Part I
   Air Transport Association of America

4. Integrated Air Traffic Control System
   AAF Electronics Subdivision
   Advisory Group on Air Navigation

5. Application of Existing Techniques to Development of Improved System of Air Traffic Control
   Airborne Instruments Laboratory

6. Report of the Subcommittee of the Committee on Interstate and Foreign Commerce of the House of Representatives entitled "Aids to Air Navigation and L.inding".

7. Automatic Blind Landing Equipment
   Tucker Industries, Inc.

8. A New Type of Airways Navigation
   Luis Alvarez, University of California

9. Standards for the Control of Instrument Flight Rule Traffic--ANC-IFR

10. Automatic Altimeter Setting System
    Kollsman Instrument Division of Square D Company

11. Interim Report on Approach Traffic Control Radar
    L. U. Hibbard, Council for Scientific and Industrial Research of Australia

12. Surveillance Approach Traffic Control
    H. K. Morgan, Bendix Radio

13. Radar as an Interim Aid to new York Air Traffic Control
    C. A. Fowler, H. B. Abajian, and G. C. Comstock
    Airborne Instruments Laboratory

14. Synchrometric Technique
    Panoramic Radio Corporation

15. Air Traffic Control
    General Railway Signal Company

16. An Evaluation of the Traffic Capacity of a Fised Block Traffic Control System in the Approach Zone
    W. R. Rantbo and R. C. Wheeler, Jr.
    Airborne Instruments Laboratory

17. Investigation of the Capacity of a Moving Block Traffic Control System
    D. A. Ewing, A. B. Faunce, J. N. Marshall, R. W. K. Smith
    Radio Corporation of America

18. An Analysis of the Problem of Aircraft Collision Prevention
    Richard N. Close,
    Airborne Instruments Laboratory

19. RTCA Recommended United States Policy for Air Navigation Communication - Trnific Control

20. Fundamentals of Air Traffic Control
    P. J. Herbst,
    Radio Corporation of America

21. Conclusions of Committee to Investigate Use of Commercial Broadcast Stations as Navigational Aids
    Charles R. Banks, Aeronautical Radio, Inc.
    Raymond C. Woodward, Civil Aeronautics Administration
    H. S. Stokes, Civil Aeronauitics Administration

22. The Block System for Airway Traffic Control, Pamphlet 630
    General Railway Signal Company

23. VHF Omni-Directional Navigation System
    Bendix Radio

24. Theoretical Errors of Position as Obtained from the Offset Course Computer
    Bendix Radio

25. A System for Air Traffic Control in the Terminal Area
    Hughes Aircraft Company

26. Teleregister Automatic Aids for Air Traffic Control
    The Teleregister Laboratories, New York

27. TSELC-SP-2 Report of the Electronics Sub-Division Advisory Group on Air Navigation
    Air Technical Service Command
    Wright Field, Dayton, Ohio

28. PICA0 - Final Report - First Session
    COT Division Document 2008

29. Stratograph
    Panoramic Radio Corporation

30. Survey and Analysis of Air Traffic and Air Traffic Control in the New York Metropolitan Area
    Port of New York Authority

31. Comparison of Methods of Challenging an Airborne Beacon
    Hazeltine Electronics Corporation

32. Lanac Air and Marine Navigation
    Hazeltine Electronics Corporation

33. Aerial Navigation and Traffic Control
    Federal Telecommunications Laboratories

34. Coordinated Air Traffic
    Sperry Gyroscope Company

35. Tricon System of Air Navigation and Traffic Control
    General Electric Company

36. Final Acts of the International Telecommunication Conference, At!nntic City 1047

37. Study of Aeronautical Frequency Allocations above 400 Mc.
    Final Report of RTCA Special Committee 27

38. NAVAR, Flexible Coordinated Series of Radio Aids to Air Navigation and Traffic Control
    Federal Telecommunications Laboratories

39. The Application of a Moving Block System to RCA Teleran
    W. W. Felton,
    Franklin Institute

40. Interim Report on the Further Development of a System for Airport Traffic Guidance and Control
    Sperry Gyroscope Company

APPENDIX VI

MEMBERSHIP - SPECIAL COMITTEE SC3 1 - AIR TRAFFIC CONTROL

PHASE I - Development of Basic Air Traffic Control Principles

CHAIRMAN: Colonel J. B. Duckworth, Department of the Air Force
VICE-CHAIRMAN: H. K. Morgan, Bendix Radio
SECRETARY: L. M. Sherer. RTCA

Members and Alternates

Aeronautical Radio, Inc.
    Blake Cahill (Northwest Air Lines)
Air Line Pilots Association
    G. M. Sheridan (Eastern Air Lines)
Air Transport Association of America
    R. Fordyce (Pan American Airways)
    V. I. Weihe
Aircraft Owners and Pilots Association
    L. R. Wilson, Jr.
Civil Aeronautics Administration
    J. L. Huber
    H. S. Stokes
    W. E. Jackson
    C. F. Timmerman
Civil Aeronautics Board
    R. L. Froman
Department of the Air Force
    Colonel S. A. Mundell
    Lt. Colonel M. E. Gravenberg
Department of the Navy
    Commander W. M. Hawkes
    Commander E. M. Morgan
Department of State
    H. F. Amrine
Department of the Treasury (u. S. Coast Guard)
    Lt. Commander B. F. Engel
    Ensign W. H. Yates
Federal Communications Commission
    J. R. Evans
Radio Manufacturers Association
    Paul Adams (Federal Telecommunications Laboratories)
    J. E. Browder (Sperry Gyroscope Company)
    H. K. Morgan (Bendix Radio)

Advisors and Observers

E. L. Adams, The Teleregister Corporation
B. A. Denicke, Civil Aeronautics Administratioo
P. D. Doersam, Douglas Aircraft Company
W. F. Dunn, The Teleregister Corpration
J. W. Leas, Air Transport Association of America
D. K. Martin, Bell Telephone Laboratories
K. Mcllwain, Hazeltine Electronics Corporation
D. Mitchell, Federal Communications Commission
T. A. Murrell, Office of the Secretary of War
Dr. R. J. Nicholson, Watson Laboratories. U.S.A.F.
H. I. Rothrock, Department of the Navy
E. E. Schwalm, Department of the Navy
R. W. K. Smith, Radio Corporation of America
J. C. Spencer, Department of the Navy
M. Wallace, Panoramic Radio Corporation
S. N. Wight, General Railway Signal Company

PHASE II - Equipments and Procedures Required to Implement the Air Traffic Control Principles

CHAIRMAN: Captain A. S. Born, Department of the Navy
VICE-CHAIRMAN: J. R. Cunningham United Air Lines
SECRETARY: L. M. Shcrer, RTCA

Members and Alternates

Aeronautical Radio, Inc.
J. R. Cunninghaul (United Air Lines)
E. A. Post " "
. Airline Pilots Association
G. M. Sheridan (Eastern Air Lines)
Air Transport Association of America
R. W. Ayer (American Air Lines)
S. P. Saint " " "
V. I. Weihe
Aircraft Owners and Pilots Association
L. R. Wilson, Jr.
Civil Aeronautics Administration
J. L. Huber
H. S. Stokes
W. E. Jackson
P. T. Astholz
Civil Aeronautics Board
R. L. Froman
Department of the Air Force
Colonel S. A. Mundell
Colonel J, F. Taylor
N. Braverman
Department of the Navy
Captain A. H. Bergeson
H. I. Rothrock
Lt. Commander I. L. McNally
Lt. Commander R. J. Connolly
Department of State
H. F. Amrine
Department of the Treasury (U. S. Coast Guard)
Lt. Commander B. F. Engel
Ensign W. H. Yates
Federal Communications Commission
J. R. Evans
W. B. Hawthorne
Radio Manufacturers Association
R. W. K. Smith (Radio Corporation of America)
H. H. Spencer " "
K. Mellwain (Hazettine Electronics Corporation)
W. H. Wilson "
P. C. Sandretto (International Telecommunications Laboratories

Advisors and Observers

R. L. Adams, The Teleregister Corporation
A. A. Anderson, Departnierit of the Navy
J. A. Apuli, Department of the Navy
B. R. Boymel, Department of the Navy
F. Bradley, Sperry Gyroscope Company
J. E. Browder, Sperry Gyroscope Company
C. W. Burcky, The Teletype Corporation
C. W. Carnlody, Civil Aeronautics Administration
R. I. Colin, Federal Telecommunication Laboratories
T. E. Daniels, Aeronautical Radio Inc.
Harry Davis, Watson Laboatories U.S.A.F.
Colonel J. K. DeArmond, Joint Communications Board
D. Dettinger, The Teleregister Corporation

A, C. V. Dlehl, Department of ... ·v
W. Edwards, Department of the ...
Dr. D II. Ewing, Radio Corporation .4merica
W. W. Felton, Franklin Institute
O. S. Field, General Railway S... Company
J. S. Freehafer, General Rail... ...a l Company
I,. H. Hayden, civil Aeronautics Administration
E. F. Herzog, General Electri... ...any
M. L. Jeffers, Department of t...
R. C. Jensen, General Electric ... ...ny
N. A. Jolley, Civil Aeronautics ... ...istration
R. H. Jones, Department of the ...
C. C. Lasher, General Electric ... ...a ny
J. W. Leas, Air Transport Ass... ... of America
A. W. League, Civil Aeronautics ...inistration
G. B. Litchford, Sperry Gyros... Company
T. N. Marshall, Radio Corporation America
D. K. Martin, Bell Telephone L... Series
T. W. Miller, The Teleregister ... ...ration
H. K. Morgan, Bendix Radio
Dale Nelson, The Teleregister ... ...ation
Dr. R. J. Nicholson, Watson La... ...ies, U.S.A.F.
W. C. Norris, Engineering Res... ...viation, Inc.
S. A. Pettingill, Federal ... ...ons Commission
R. J. Parpal, Department of the
W. R. Rambo, Airborne Instruments ...aboratory
W. E. Rhoades, Air Transport ...ation of America
Major Wilbur S. Scheible, Air ... ...l Command, U.S.A.F.
E. L. Schmidt, The Teleregistration ...oration
H. J. Schrader, Radio Corportation America
E. E. Schwalm, Department of ... v
J. T. Semans, General Railway ... Company
R. J. Shank, Hughes Aircraft C...
J. C. Spencer, Department of ... ·v
G. V. Stelzenmuller, Federal C... ...ications Commission
C. B. Tompkins, Engineering ... ...h Associates, Inc.
M. Wallace, Panoramic Radio ... ...ation
J. B. Watson, Civil Aeronautic... ...istration
W. D. White, Airborne Instru... Laboratory
S. N. Wight, General Railway ... Company

All meetings of Committee SC31 were ... Washington, D. C. Phase I completed its activities ... Series of twelve (12) meetings which be... ...uly 30, 1947, and concluded on August 17, 1947. ... II met continuously, in either general committee meetings, from October 7, 1947, to Feb-...ry 14, 1948.

CORRECTIONS OF PAPERS 9-48/DO-9 and 10-48/DO-10

This report incorporates the following corrections of the text and charts of the mimeographed **copies** of the summary and main report **of** Special Committee SC31 - Air Traffic Control - Papers 9-48/DO-9 dated February 16, 1948, and IO-48/DO- 10 dated February 17, 1948, respectively.

1. Page 9, Fourth Paragraph
   The figures $897 and $216 appeared in Paper 9-48/DO-9 as $989 and $124, respectively.

2. Page 9, Tenth Paragraph
   The figure $375.2 appeared in Paper 9-48/DO-9 as $376.2.

3. Figure 2A (following Page 29)
   The graph line for GCA is extended to indicate obsolescence after 1962 instead of 1956 as shown in Paper IO-48/DO-10.

4. Figure 2B (following Figure 2.4)
   A graph line for a low-cost, light-weight navigation receiver is added to Figure 2B of Paper **l0-48/DO- 10.**

5. Page 3 1, Paragraph c, under C. INTEGRATION
   The following is added to this paragraph:

   "However, the polarization employed for any element of the system shall not:
   (1) Prevent multiplex operation of other system elements with a common antenna system.
   (2) Prevent the attainment of omni-directional coverage.
   (3) Require an airborne antenna system which is appreciably detrtmental to the performance of high-speed aircraft."

6. Page 32, Paragraph 4d
   The words "Long Distance navigation aids and" are added; the revised wording reads:

   "Cost estimates for Long Distance navigation aids and Weather Bureau **expenditures are** not included."

7. Page 32, Paragraph 4e(3)
   The sentence "It is further assumed that the cost of a military or commercial aircraft installation is approximately three **times** that of **a** private aircraft installation" is deleted.

8. Page 33, Paragraph g
   The words "Notes 6 and 7" are changed to "Notes e and f".

9. Figure 3A (following Page 34)

   Item B5:
   The equipment designation is changed from "Addit. VHF Omni Range (VOR) Equipment" to "VHF Omni-type Range (VOR) Equipment".

   The Cost of hlanufacture of Production Type Equipment is changed from $18.5 to $15.0.

   The Quantity Assumed is changed from 370 to 300 and the abbreviation "addit." is stricken.

   The Total Cost is changed from $22.5 to $19.0.

   Item B6 :
   The abbreviation "addit." is stricken from the equipment designation.

   The Cost of Manufacture of Production Type Equipment is changed from $20.0 to $18.0.

   The abbreviation "addit." is stricken from the Quantity Assumed,

   The Total Cost is changed from $24.0 to $ 22.0.